PATTERNS AND INTENSITY OF WHITE-TAILED DEER BROWSING ON THE WOODY PLANTS OF ITASCA PARK

A MAJOR REPORT

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By

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INTRODUCTION

Because of the historical and scenic attractions of Itasca State Park, it is one of the most frequently visited state parks in our country. Its primary attractions as determined by a recent study (Klukas, 1966) are the old-growth pines and the headwaters of the Mississippi River.

The park is also an important scientific area because of the great variety of vegetative types and animal species found in the area. Many previous studies have been conducted on the biotic relationships within the park, and the published information provides an excellent background for further investigations.

Since the area has such a variety of plant communities that have been generally undisturbed, it was felt that a browse study should be conducted to determine the effects that browsing might have in limiting the regeneration of conifer species, particularily red and white pine. Another objective of the survey was to obtain some general estimate of the extent and density of conifer reproduction.

Many previous studies have been concerned with compiling deer browse preference lists and determining the availability of forage for a given area. The nutritional aspects of deer browse have also been investigated as related to their influence on preference and importance in the dietary requirements of deer. In the early stage of fieldwork it was apparent that the extent and intensity of browsing in a given area was influenced by many factors such as canopy cover, exposure, availability of browse, and the diversity of woody plant species. In the analyses of the data, particular concern was given to the quantity and diversity of woody plants as factors influencing the frequency of browsing.

History of the Itasca Deer Herd and Its Effects on the Vegetation

Personnel of the Minnesota Conservation Department observed overbrowsing conditions in the early part of this century and by 1935 the situation was considered critical. Due to public sentiment the department was unable to get Legislative approval for an open hunting season in the park at that time. The following three paragraphs of census and kill figures were obtained from Pittman-Robertson Quarterly Progress Reports, 1945-54.

Trapping and removal of deer to other areas was attempted in 1935 but proved impractical. Winter mortality when snow was deep was noted as early as 1921. Early censuses in 1935, 1937, and 1939 estimated that the population averaged 75 deer per section.

In the early days wolves were probably a factor in stabilizing the deer population, but when most of the wolves were trapped or shot starvation in severe winters became the main check on the deer population. In 1943, over 1000 dead deer were found in the north half of the park alone. Mortality was attributed to an insufficient food supply.

When the deer herd numbers were well above carrying capacity, the population fluctuated depending upon the severity of the winters. The 1945 deer herd was considered to have been at a relatively high level because of two mild winters in succession previous to opening of the hunting season.

Conservation Department personnel estimated that the 1945 hunting season resulted in a removal of almost the entire deer population from the park. An estimated 4600 hunters harvested 2048 deer in the park and an estimated 30 deer remained after the season closed. Based on kill figures, the 1945 population was estimated at 40 deer per section.

Sex and age ratios were determined for the harvested deer, and the average fawn-doe production was 0.7. It is generally believed that 1 or 1.5 fawns per doe are produced for Minnesota deer, and the Itasca figures would reflect the lack of a sufficient food supply for fawn production.. Age ratios of the Itasca deer revealed a higher proportion of old deer as compared to other areas which had been hunted consistently. The dominance of the older deer indicated that the fawn production was low and that the fawns could not survive the competition for winter foods.

Following the first open season, the average harvest estimates were: 1946 - 115, 1947 - 9, 1948 - 40, 1951 - 60, 1952 - 68, 1953 - 28, and 1954 - 44. Deer harvest checks have not been conducted since 1955. In 1961 the legislature passed a law to change the open hunting season from an annual to alternate year basis for the park.

During the period of the expanding deer population and after its decline, information regarding vegetational changes due to excessive deer populations was collected.

Fredine reported observing very little conifer reproduction in 1940. Noblet in 1943 found serious damage to forest reproduction, and he reported that all species were heavily browsed except for swamp buckthorn and alder. Leopold, et.al. (1947) considered the deer situation in Itasca just prior to 1945 as chronic due to the extent of overbrowsing.

Since 1945, data have been collected by various University and State Conservation Department officials on the Mary Lake Exclosure in the park. The exclosure was erected by Civilian Conservation Department personnel in 1937. A summary of the data collected is given in Table 1.

A comparison of the number of conifer seedlings inside and outside the exclosure reveals that heavy deer browsing was effective in preventing the establishment of coniferous regeneration as indicated by the 1946 data.

Table 1. Number of Conifer Seedlings Per Acre Inside and Outside the Mary Lake Exclosure 1946-1952.

	1946		1948		1950		1952	
Species	Inside	Out	Inside	Out	Inside	Out	Inside	Out
White pine	580	0	1100	20	930	32	1125	375
Norway pine	19	0	90	30	0	41	100	0
Jack pine	00	0	10	10	0	0	0	0
Balsam fir	0	0	10	10	0	0	100	25
Tamarack	0	0	0	0	0	5	0	0
White spruce	0	0	0	0	0	2	0	0
Total conifers	599	0	1210	70	930	80	1325	400

In 1952 Hansen and Bakuzis compared the density and height of hazel stems inside and outside the deer exclosure. They concluded that browsing had not appreciably reduced the density or the average height of hazel in that area.

The response of the vegetation to the reduction in browsing following the first open season was noted by Hansen and Brown (1952). They observed that pine seedlings were becoming established along road cuts and other areas where mineral soil was exposed. During the high deer populaion period, these seedlings were non-existent.

LITERATURE REVIEW

In the winter the white-tailed deer (Odocoileus virginianus) feeds primarily on the succulent new growth of certain trees and shrubs. Food preferences are related to the variety and quantity of food available. Food preferences are less evident for areas where there are many plant species than those where plant species are fewer (Erickson, et.al., 1961).

The factors influencing the preference for brawse species are not clearly understood. Some investigators (Leopold, et.al., 1951; Bissel, 1959; Dietz, et.al., 1958) have indicated that deer may actually prefer browse with a higher nutrient content (generally proteins). Dahlberg and Guettinger (1956) and Trippense (1948) concluded that browse plants of higher palatability did not necessarily have higher nutritional values. Th implications are that a variety of browse species are needed to satisfy the diet of deer.

Comparison of browse preferences between two geographical areas indicates that deer are adaptable and can alter their food preferences with differences in habitat (Sharp, 1958).

A general browse preference list for Minnesota, as prepared by the Conservation Department (Erickson, et.al., 1961) is given in Table 2. Krefting and Hansen (1963) compiled a list for the Tamarac National Wildlife Refuge as given in Table 3. The refuge is approximately 50 miles southwest of Itasca Park. Dogwoods (Cornus spp.), mountain maple (Acer spicatum), and ash (Fraxinus spp.) were considered as high preference species. Hazel (Corylus Cornus spp.), red pine (Pinus resinosa), spruce (Picea spp.), and snowberry (Symphoricarpos albus) were listed as less preferred species.

Table 2. Classification of Some Minnesota Plants Eaten by Deer, Based on Deer Preference. (Erickson, et. al., 1961).

Good	Medium	Poor
White Cedar	Choke Cherry	Red Pine
Red-osier Dogwood	Basswood	Tamarack
Mountain Maple	Jack Pine	Alder
Staghorn Sumac	White Birch	Bog Birch
Oaks	Some Willows	Black Spruce
Alternate-leaved Dogwood	Hazel	
Red Maple	Aspen	
Juneberry	Honeysuckle	
Hard Maple	White Pine	
Black Ash	Balsam Fir	
Mountain Ash		

Table 3. List of Woody Plants by Browse Preference Groups (Tamarac National Wildlife Refuge) (Krefting, L.W. and H.L. Hansen, 1963).

High Preference	Medium Preference	Low Preference
Amelanchier spp.	Betula papyrifera	Corylus americana
Cornus alternifolia	Lonicera dioca	C. cornuta
C. racemosa	L. hirsuta	Crataegus spp.
C. rugosa	Pinus banksiana	Diervilla lonicera
C. stolonifera	P. strobus	Ostrya virginiana
Fraxinus pennsylvanica	Prunus pennsylvanica	Pinus resinosa
Prunus serotina	Quercus rubra	Populus tremuloides
P. virginiana	Rhus radicans	P. grandidentata
Quercus macrocarpa	Rosa blanda	Rubus pensilvanicus
Tilia americana	Salix bebbiana	R. idaeus
Viburnum rafinesquianum	S. humilis	Smilax spp.
V. trilobum	Ulmus americana	Symphoricarpos spp.
	Vaccinium angustifolium	

Effects of browsing on vegetation

During periods of relatively high populations, estimates of browsing damage were made in many states, and the forest reproduction was considered to be in critical condition (Swift, 1948; DeBoer, 1947; Leopold, 1945). DeBoer found severe damage to conifers and hardwoods in a 1947 statewide survey in Wisconsin. He reported that 71% of the hardwoods and 52% of the conifers were browsed in Central Wisconsin. In comparison only 18% of the hardwoods and 8% of the conifers were browsed on the Lac du Flambeau Indian Reservation, where unrestricted hunting was permitted.

Stoeckler, et.al., (1957) reported that a prolonged period (6-8 years) of rather low deer populations was needed in second growth hardwood-hemlock stands in Wisconsin to permit successful regeneration and adequate growth of the understory seedlings. They found that even though sugar maple tolerated rather heavy browsing, the seedlings were stunted. The average height for sugar maple reproduction in exclosures was twice that on the control plots.

In comparing the number of stems of sugar maple per acre, Webb (1954) in New York found no significant diffferences between browsed and unbrowsed areas. He concluded that after 15 years of protection, deer were not an important limiting factor in the establishment of any tree, shrub, or herbaceous plant in an uncut mature northern hardwood stand.

Contrary to Webb's conclusion, Curtis and Rushmore (1958) stated that deer in the Adirondacks were responsible for the predominance of red spruce (Picea rubens) and beech (Fagus grandifolia) and the reduction of hard maple (Acer saccharum) and yellow birch (Betula alleghaniensis) in the forest composition.

Beals, et.al. (1960) found that the lightest deer browsing pressure resulted in some vegetational changes for the Apostle Islands. Deciduous browse was taken independently of the kind of evergreen present, and even with an abundance of the highly preferred yew (Taxus canadensis), a fair proportion of deciduous browse was eaten.

Cottam and Curtis (1956) also noted that deer influence the structural composition of forest communities. By comparing browsed and unbrowsed forest communities, they developed a list of plant increasers, decreasers, and invaders for northern Wisconsin. The list of species was used for giving a quantitative assessment of deer damage to forest stands.

Snowshoe hares (Lepus americanus) may also have significant effects on vegetation. Ostrum (1942) and Hough (1949) found that in Pennsylvania rabbits had a much greater effect than deer on the vegetation. Rudolph (1950) found that 43% of 55 older Minnesota pine plantations had hare injury as compared to 10% for 239 older plantations in Michigan, where conditions were less favorable for hares.

At an early peak population of snowshoe hares in Minnesota and Wisconsin (1923-25) Kittredge (1929) reported severe damage to conifer plantations. He found 100% damage to white pine (Pinus strobus), 78% to white spruce (Picea glauca), and 55% to red pine. More than half of the white pine and spruce had at least 70% of their new growth removed. Red pine suffered the least damage as they were planted in an open area, unfavorable as habitat for hares.

To determine actual effects of browsing or simulated browsing on conifers, growth response has been quantitatively measured. Comparing the average heights six years after planting for protected and unprotected Douglas-fir (Pseudotsuga menziesii) seedlings, Roy (1960) found that deer browsing reduced the average height by an amount equal to 3.6 years of growth. The severity of browsing damage appeared to be related to the amount of preferred browse growing on an area.

Krefting and Stoeckler (1953) conducted a study of simulated browsing on recently established nursery stock seedlings. One inch of the terminal shoot was clipped for jack pine (Pinus banksiana) and red pine seedlings for two and three years in succession. Jack pine was found to be more resistant than red pine to mortality from clipping. For all clipping frequencies, jack pine suffered a loss of only 5% as compared to 13% for red pine. After 6 years it was found that clipping had a greater effect on red pine than on jack pine heights. Jack pine had only 9% reduction compared to 25% for red pine.

Another phase of the study compared the sensitivity of four species of conifer seedlings to successive browsing. The species were rated from least to most sensitive to browsing damage as follows: white spruce, jack pine, white pine, and red pine. White pine was considered less sensitive than red pine because it produced new leaders sooner. McHattie (1963) found that although browsed, jack pine had more height growth than white pine or white spruce.

In another study of the effects of simulated browsing, Marshall, et.al. (1955) found that white pine was more resistant than red pine to overbrowsing. The authors worked with older seedlings and clipped every branch on the seedling. They clipped the branches at three levels of intensity and repeated the operation for successive years. They concluded that differences in the results of simulated browsing studies may have been due to differences in site quality, to a change in the responses of the trees with increasing size, or perhaps other unknown factors. The effects of overbrowsing for 1, 2, or even 3 years may well be tolerated by well established conifers, but the authors indicated that action may be necessary to prevent mortality from any increase in repetitive or intensified browsing.

In summary De Vos (1958) has warned that to study browsing pressure as a modifying agent to the forest community is a complicated matter because many interrelated factors are involved. "Conclusions will depend on the forest type, age of the stand, species composition, stand density, as well as edaphic factors and exposure." The effect of browsing on community structure may also vary for different successional stages. "Overbrowsing" may be misinterpreted because trees may have died anyway.

STUDY AREA

The park is located in the northwestern quarter of Minnesota. The topography and vegetation of the area are highly varied. The kettle and drum topography in the park is characteristic of the rolling areas found in glacial terminal moraines. The park lies near the forest-prairie "fringe". The hardwoods from the south and the conifers from the north and east invade the area and add to the complexity of the floristic composition. The forest communities are heterogeneous, but they have been classified into the following major forest cover types by the School of Forestry:

Aspen-Birch - Consists of approximately 13,000 acres and comprises the greatest acreage in the park. The dominant species include quaking and bigtooth aspen and paper birch. Oaks and maples are associated species that occur in fewer numbers.

Red and White Pine - The area of this cover type includes approximately 6500 acres and is characterized by mature and overmature red and white pine with minor components of upland hardwoods of many species.

Jack Pine - The approximate 1900 acres of this cover type includes jack and red pine as the dominant species with minor associates of aspen, birch, and red maple.

Spruce-Fir - The extent of this cover type includes about 1600 acres. Balsam fir is usually the dominant species in the stand although occasionally white spruce is a major component. Paper birch, aspen, elm, red maple, and ash are found as minor components.

Northern Hardwoods - This type consists of approximately 1500 acres, and sugar maple, red maple, basswood, and elm are the more common species present. Old-growth pines, aspen, birch, and oaks occur frequently as minor species.

Lowland Hardwoods - This type consists of approximately 400 acres with black ash and elm as the dominant species. Other hardwoods represent the minor species present.

Black Spruce - Black spruce is the dominant species in this cover type that consists of approximately 700 acres. Tamarack is the only other major tree species present.

Cedar - A small tract of approximtely five adres exists near the west end of the Bohall Trail and less than ¼ mile from Lake Itasca. Norther white cedar is the dominant species with minor associates of black spruce, birch, elm, and red maple.

The depth of winter snow is an important factor limiting the movements of deer. During periods of great snow depths without a solid crust, deer movements are restricted and "yards" are formed. If yarding is prolonged for an extended period of time, the selection of food species will depend primarily on availability rather than quality of the forage. Climatological data concerning average snow depth for the park ~~was~~ were not available, but the mean monthly snowfall data is presented in Table 4.

Table 4. Mean Snowfall for Itasca Park — 1913-52 (US Dept. of Commerce)

Jan.	Feb.	March	April	May	Sept.	Oct.	Nov.	Dec.
8.5	7.6	8.2	4.2	0.6	0.2	2.0	6.2	9.2

METHODS

Forest communities representative of particualr forest cover types were selected for sampling. A forest community was classified as a particular cover type on the basis of the dominant tree species in the forest canopy. The number of communities sampled for each respective cover type was as follows: Red and White Pine--14, Jack Pine--9, Aspen-Birch--13, Northern Hardwoods--11, White Spruce-Fir--4, Lowland Hardwoods--3, Black Spruce--3, and Cedar--1. The approximate locations of the communities sampled are shown in Figure 1.

Seral communities of different stages were selected for sampling to give representative results of the broad spectrum of environmental conditions that exist for each cover type. Geographical distribution of the communities within the park was also considered in selecting sample areas. Spatial distribution of sample areas was considered important in reducing bias that may have resulted from collecting information from an area that may have received heavy localized deer use. Also by locating sample areas throughout the park, an opportunity existed to discover any areas of winter deer concentrations or yarding. Accessibility within the park and the extent and distribution of some cover types limited the number of sample areas.

Each forest community selected was sampled by systematically locating 1/500-acre circular plots within the community. The number of plots established within the communities ranged from 8 to 40. The total number of plots within each cover type was: Red and White Pine --114, Jack Pine--100, Aspen-Birch--123, Northern Hardwoods--114, White Spruce-Fir--74, Lowland Hardwoods--50, Black Spruce--59, and Cedar--40.

Some of the plots investigated had been permanently established by V. Kurmis and D. Ness who were collecting information concerning other ecological problems in the park.

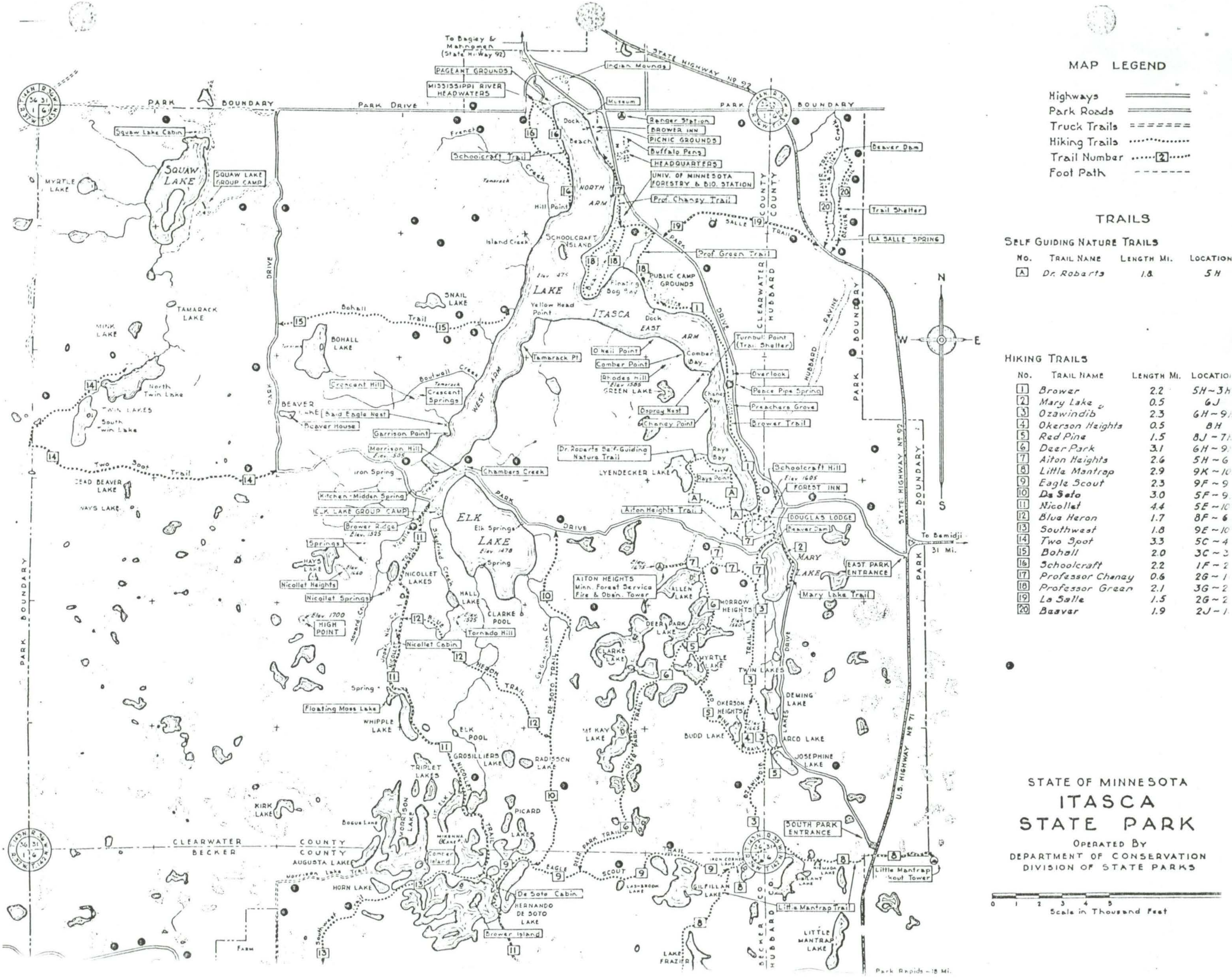


Fig. 1. Approximate locations of Forest Communities Sampled.

The level of data collection involved two phases during the period of field work, July 1 through Spptember 15, 1965. The initial phase included an intensive collection of data that was considered to have provided addtional information concerning the extent and intensity of browzing.

For each plot the total number of stems of woody plants greater than one foot but less than seven feet in height was recorded by species. Woody plants within this given height range were considered as available browse under the normal winter snow conditions.

Total age was determined by counting the annual node scars, and height was estimated to the nearest inch. The degree of browsing was also estimated for each individual browsed conifer stem. This was determined by comparing the browsed stem with an unbrowsed stem and and estimating the utilization of the annual growth that had occurred. Browse Form Classes were used to rate the degree of browsing as illustrated in Figure 2.

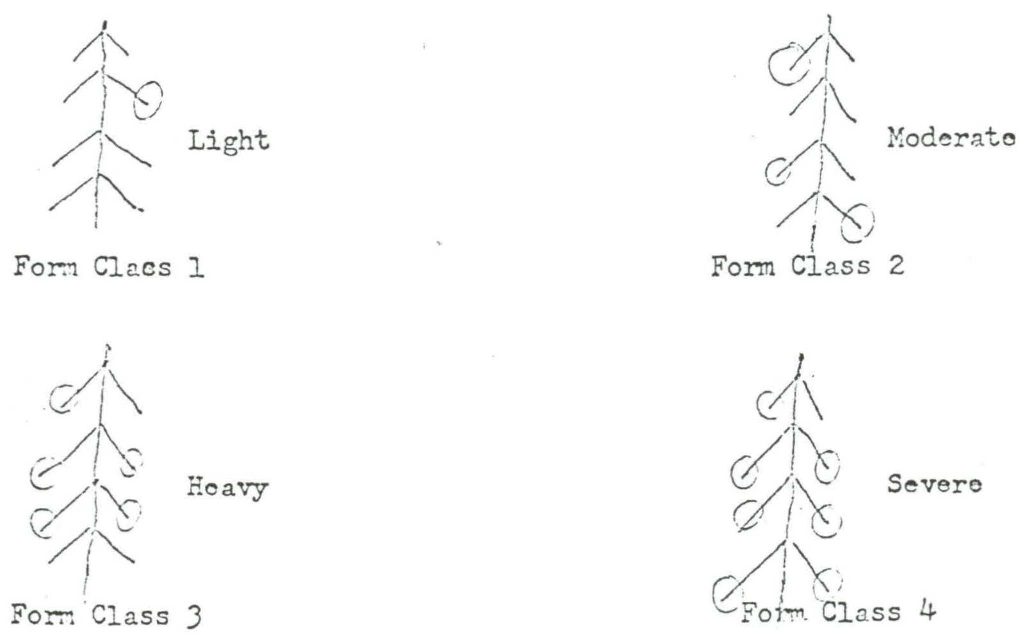


Fig. 2. Illustrative Examples of the Degree of Browsing.

Data recorded for each conifer seedling included species, age, height, length of the 1965 terminal shoot, and the number of living branches arising from the stem bole. Only branches developed prior to 1965 were counted. The number of branches browsed was recorded and attributed to the appropiate browsing species, deer and/or hare. If a specific branch had twigs that had been browsed by both deer and hare, the tally was recorded to the animal that caused the most damage to that particular branch.

If the terminal shoot ahd been browsed, it was determined whether the browsing had resulted from a deer or hare. If the shoot was damaged and not browsed, the damage was recorded as unknown.

Since blister rust was known to be an important pathological factor limiting the establishment and longevity of white pine in many parts of the Lake States, observations of seedlings infected with the disease were also recorded.

Because of time limitations information collected during the survey was reduced in the second phase of the fieldwork. Ages of browse species were not determined and heights of deciduous browse species were recorded by two-foot classes. The number of branches was not determined for conifer seedlings; but for browsed stems only the cause,deer or hare, was recorded.

RESULTS

Browse preferences

A browse preference list for Itasca Park was compiled on the basis of the frequency that species were browsed, and the results are given in Table 5. The number of observations includes all deciduous stems between one and seven feet in height and conifers less than one inch in diameter at breast height. Common and scientific names of all plant species listed are given in the appendix.

White and jack pine were highly preferred conifers while white and black spruce and red pine were seldom browsed. Balsam fir was only moderately preferred by deer.

Red maple and elm were the only deciduous tree species with a high preference rating. Basswood, black and green ash, aspen, bur and red oaks, and sugar maple were of medium preference. Ironwood was of low preference.

The ranking of the browse species was quite similar to other Minnesota browse preference lists except for a few species. Jack and white pine, rose, prairie willow, and elm received higher ratings for Itasca; and downy arrowwood, panicled dogwood, and bur oak received lower ratings for Itasca.

Hare browsing was more frequent on conifers than on deciduous species. Balsam fir was nipped as frequently as jack pine. White and black spruce and red pine were more frequently browsed by hare than by deer. The percent of seedlings browsed by hare as given in Table 5 is a conservative estimate because it does not include seedlings that were both deer and hare browsed. It was found to be very difficult to distinguish between hare and deer browsing on the smaller twigs of conifers, and many of the injuries were covered with pitch

Table 5. Browse Preference List for Itasca State Park.

Species	No. of Observations	% Deer Browsed	% Hare Browsed	Preference Rating
Cornus stolonifera	349	92	1	
Acer spicatum	587	90		
Cornus alternifolia	105	89		
Viburnum trilobum	19	79		
Pinus strobus	190	75	8	High
Pinus banksiana	16	75	25	
Salix humilis	222	74	2	
Cornus rugosa	305	72		
Rosa spp.	309	70	7	
Lonicera oblongifolia	126	70		
Ulmus americana	151	69	3	
Acer rubrum	299	68	2	
Salix spp. (lowland)	111	68		
Diervilla lonicera	484	62	1	
Tilia americana	69	60	1	
Prunus serotina	30	58		
Amelanchier spp.	619	56	2	
Fraxinus nigra	394	56	2	
Populus tremuloides	127	54	6	
Lonicera spp. (upland)	62	54		
Fraxinus pennsylvanica	224	46		
Prunus pennsylvanica	42	46		Medium
Prunus virginiana	413	45		
Quercus macrocarpa	56	45	7	
Quercus rubra	148	42	3	
Betula papyrifera	990	42	3	
Acer saccharum	1600	37		
Cornus racemosa	110	34		
Viburnum rafinesquianum	381	30		
Abies balsamea	261	28	25	
Alnus crispa	143	27	2	
Corylus cornuta	7338	16		
Corylus americana	207	15		
Betula pumila	100	14		Low
Rhamnus alnifolia	440	14		
Alnus rugosa	168	13	8	
Ostrya virginiana	316	12	3	
Symphoricarpos albus	183	5	4	
Picea glauca	26	4	39	
Picea mariana	332	3	9	
Pinus resinosa	27	0	37	
Dirca palustris	118	0		

exudates. Rose, cherry, aspen, and speckled alder were some of the more frequently hare browsed deciduous plants.

Differences in ranking of browse species between two distinct areas was considered to be a result of browse species availability, diversity of vegetation, and/or forest cover conditions. The canopy of the forest vegetation was considered important not only for protecting deer and hares from adverse weather conditions and predators, but also as a factor influencing the composition of the lesser vegetation. Based on the number of sample plots; estimates of browse density, number of available browse stems per acre, were made for the eight forest cover types as given in Tables 6 through 13. The species are listed according to the percent of the stems that were browsed by either deer or hare.

In the red and white pine cover type (Table 6), alternate-leaved and round-leaved dogwoods, white pine, red maple, and rose were extensively browsed but were of relatively low density. Beaked hazel was the most abundant species with an average density of 10,843 stems per acre of which only 15% were browsed. Juneberry and balsam fir ranked second and third in abundance with 918 and 773 stems per acre, respectively. These two species were of medium preference.

Ninety-five percent of the white pine seedlings were browsed in the jack pine cover type (Table 7). Seedling density of white pine was estimated at 520 stems per acre. Prairie willow, rose, and juneberry were found to be relatively abundant and highly preferred. Again the two low preference hazel species dominated in abundance with an average of 7980 stems per acre.

Table 6. Browse Preference List for the Red and White Pine Cover Type.

Species	No. Stems/Acre	% Browsed
Cornus alternifolia	154	94
Cornus rugosa	119	93
Acer spicatum	66	87
Pinus strobus	215	73
Acer rubrum	267	72
Rosa sp.	338	70
Populus tremuloides	154	66
Diervilla lonicera	373	61
Salix humilis	153	58
Prunus virginiana	430	57
Amelanchier sp.	918	59
Abies balsamea	773	55
Quercus rubra	132	50
Lonicera sp.	123	46
Alnus crispa	267	38
Betula papyrifera	77	37
Viburnum rafinesquianum	211	27
Corylus cornuta	10,843	15
Corylus americana	233	9
Symphoricarpos albus	246	4

Table 7. Browse Preference List for the Jack Pine Cover Type.

Species	No. Stems/Acre	% Browsed
Pinus strobus	520	95
Pinus banksiana	80	95
Acer rubrum	55	91
Prunus serotina	55	82
Prunus pennsylvanica	80	81
Salix humilis	805	80
Rosa sp.	950	79
Populus tremuloides	175	73
Amelanchier sp.	1140	70
Prunus virginiana	180	64
Diervilla lonicera	1100	55
Corylus cornuta	7685	26
Alnus crispa	295	20
Corylus americana	565	18
Symphoricarpos albus	390	9

Ecological conditions appreared to be limiting the number of highly preferred browse species in the aspen-birch type (Table 8) as indicated by the low density of these species. Round-leaved dogwood was the most common of the high preference species. Downy arrowwood, panicled dogwood, and juneberry were relatively abundant but only 33, 32, and 32 percent, respectively, of the stems were browsed. Only 12% of the beaked hazel stems were browsed and the species occurred at its greatest density of 11,553 stems per acre in the aspen-birch type.

Alternate-leaved dogwood, mountain maple, and red maple were highly preferred browse species in the northern hardwood type (Table 9). Many of the high preference species were present in this cover type, but they were not browsed as frequently as in other cover types. Sugar maple was the most abundant species with 6917 stems per acre but only 36 % of the stems were browsed. Hazel and ironwood were important species in terms of density but were of low preference.

The spruce-fir cover type (Table 10) had very few browse stems per acre. Black ash was the most abundant species with 608 stems per acre and was followed by choke cherry with 223 stems per acre. All species present were browsed more frequently than was the case in any other cover type.

Mountain maple was the most important browse species in the cedar cover type (Table 11) because it was the most abundant species with 1875 stems per acre and was highly preferred - 95% browsed. Honeysuckle, elm, and red-osier dogwood were also highly preferred species and averaged 725, 625, and 400 stems per acre; respectively. Black ash was also common, 400 stems per acre, but was browsed less frequently than the previously mentioned species.

Table 8. Browse Preference List for the Aspen Cover Type.

Species	No. Stems/Acre	% Browsed
Rosa sp.	126	81
Acer rubrum	154	74
Diervilla lonicera	667	73
Cornus rugosa	1053	71
Salix humilis	199	69
Quercus macrocarpa	110	48
Prunus virginiana	337	45
Quercus rubra	203	42
Acer saccharum	169	41
Populus tremuloides	187	39
Viburnum rafinesquianum	866	34
Cornus racemosa	463	33
Amelanchier sp.	472	32
Fraxinus nigra	77	32
Prunus pennsylvanica	102	28
Betula papyrifera	89	27
Abies balsamea	126	26
Alnus crispa	89	23
Symphoricarpos albus	122	17
Corylus cornuta	11,553	11
Corylus americana	154	8

Table 9. Browse Preference List for the Northern Hardwood Cover Type.

Species	No. Stems/Acre	% Browsed
Cornus alternifolia	307	86
Acer spicatum	825	77
Acer rubrum	763	65
Cornus rugosa	53	58
Populus tremuloides	114	54
Fraxinus pennsylvanica	92	52
Tilia americana	215	51
Amelanchier sp.	136	48
Ulmus americana	189	40
Quercus rubra	250	37
Acer saccharum	6917	36
Prunus virginiana	702	28
Fraxinus nigra	360	26
Corylus cornuta	1706	21
Lonicera sp.	61	21
Quercus macrocarpa	53	17
Ostrya virginiana	1281	15
Dirca palustris	79	0

Table 10. Browse Preference List for the White Spruce-Balsam Fir Cover Type.

Species	No. Stems/Acre	% Browsed
Populus tremuloides	81	100
Amelanchier sp.	61	100
Abies balsamea	61	100
Acer rubrum	68	90
Fraxinus nigra	608	86
Corylus cornuta	196	76
Diervilla lonicera	54	75
Prunus virginiana	223	73
Tilia americana	68	70
Ostrya virginiana	61	33
Betula papyrifera	61	22
Symphoricarpos albus	115	12

Table 11. Browse Preference List for the Northern White Cedar Cover Type.

Species	No. Stems/Acre	% Browsed
Amelanchier sp.	100	100
Rosa sp.	50	100
Acer spicatum	1875	95
Lonicera sp.	725	91
Ulmus americana	625	90
Cornus stolonifera	400	88
Acer saccharum	62	80
Corylus cornuta	338	78
Betula papyrifera	150	75
Quercus macrocarpa	50	75
Fraxinus nigra	1400	60
Salix sp.	62	60
Rhamnus alnifolia	362	28
Betula alleghaniensis	162	23

Table 12. Browse Preference List for the Black Spruce Cover Type.

Species	No. Stems/Acre	% Browsed
Cornus stolonifera	1338	92
Salix sp.	881	68
Abies balsamea	178	62
Lonicera sp.	305	50
Amelanchier sp.	119	43
Corylus cornuta	144	35
Betula pumila	838	15
Alnus rugosa	958	13
Rhamnus alnifolia	2050	12
Picea mariana	271	12

Table 13. Browse Preference List for the Lowland Hardwood Cover Type.

Species	No. Stems/Acre	% Browsed
Acer spicatum	2250	96
Cornus stolonifera	1550	95
Abies balsamea	220	95
Viburnum trilobum	110	91
Lonicera sp.	320	84
Ulmus americana	520	83
Corylus cornuta	270	63
Fraxinus nigra	850	61
Betula papyrifera	100	60
Rhamnus alnifolia	1690	13

Red-osier dogwood averaged 1338 stems per acre in the black spruce cover type and 92% of the stems were browsed as shown in Table 12. Lowland willows ranked second in browsing frequency and averaged 881 stems per acre. This cover type had characteristically a high density of low preference species such as bog birch, speckled alder, and buckthorn which averaged 838, 958, and 2060 stems per acre; respectively.

In the lowland hardwood cover type (Table 13) all species were browsed with a frequency greater than 60% except for buckthorn which had a density of 1690 stems per acre and only 13% were browsed. Mountain maple, red-osier dogwood, and black ash constituted the major preferred species with 2250, 1550, and 850 stems per acre and a browsi ng frequency of 96, 95, and 61 %; respectively.

Data related to the density, frequency of browsing, and stem height composition of high preference deciduous species, according to Table 5, were summarized to compare the use and composition of browse for the various forest cover types and the results are given in Table 14.

Table 14. Density, Frequency of Browsing, and Height Composition of High Preference Deciduous Browse Species in Various Forest Cover Types.

Cover Type	No. of Stems/Acre	Percent Browsed	Stem Ht. Composition (%) 1-3'	3-5'	5-7'	7' +
Spruce-fir	135	95	95	0	0	5
Lowland Hardwoods	4770	93	43	29	14	14
Cedar	3790	93	51	31	10	8
Jack Pine	1870	80	80	14	5	1
Black Spruce	2580	78	78	12	4	6
Red and White Pine	1010	77	78	13	4	5
Aspen-Birch	1560	72	43	27	11	19
Northern Hardwoods	2160	70	69	15	10	6

The lowest frequency of browsing (70%) of the most palatable species occurred in the northern hardwood communities. The spruce-fir, lowland hardwood, and cedar communities ranked the highest with over 90% of the stems browsed. Jack pine, black spruce, red and white pine, and aspen-birch communities followed in that order.

The density of available browse varied considerably between forest cover types. The spruce-fir type averaged only 135 stems per acfe; and the highest density, 4770 stems per acre, occurred in lowland hardwood communities. The ranking of the remaining cover types based on density of high preference browse was as follows (highest to lowest): cedar, black spruce, northern hardwoods, jack pine, aspen-birch, and red and white pine.

The height composition of the high preference species was calculated for four height classes: 1-3', 3-5', 5-7', and 7'+ which was considered as unavailable browse. In the spruce-fir type, 95% of the stems were less than 3 feet tall and the remaining stems were over 7 feet. In the jack pine, black spruce, and red and white pine communities, over 78% of the stems were less than 3 feet in height. The northern hardwood communities had 69% of the total stem heights in the 1 to 3-foot class. Cedar had relatively the highest composition within the 3 to 5-foot class, and the highest composition within the 5 to 7-foot class occurred in lowland hardwood communities. Comparison of the relative abundance of available and unavailable high preference species in the various cover types revealed that jack pine communities had the highest percent (99) of available stems and aspen-birch communities had the lowest with 81 percent.

Diversity of browse species

The relative composition of low, medium, and high preference browse species was determined for each forest community sampled. The results are presented graphically, using the triangular coordinate method, for each forest cover type in Figures 3 through 7. Figure 8 is a composite for all communities. Each stand was numbered as indicated on the graphs for future reference.

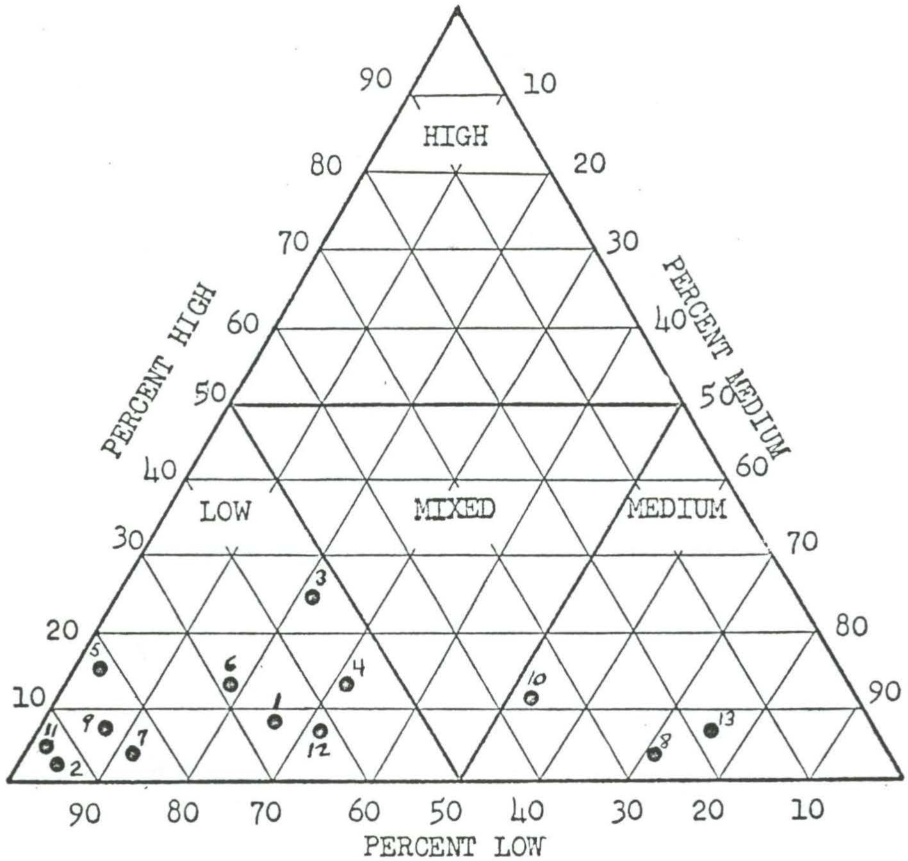


Fig. 3. Percent Composition of Preference Groups in Aspen-Birch Communities

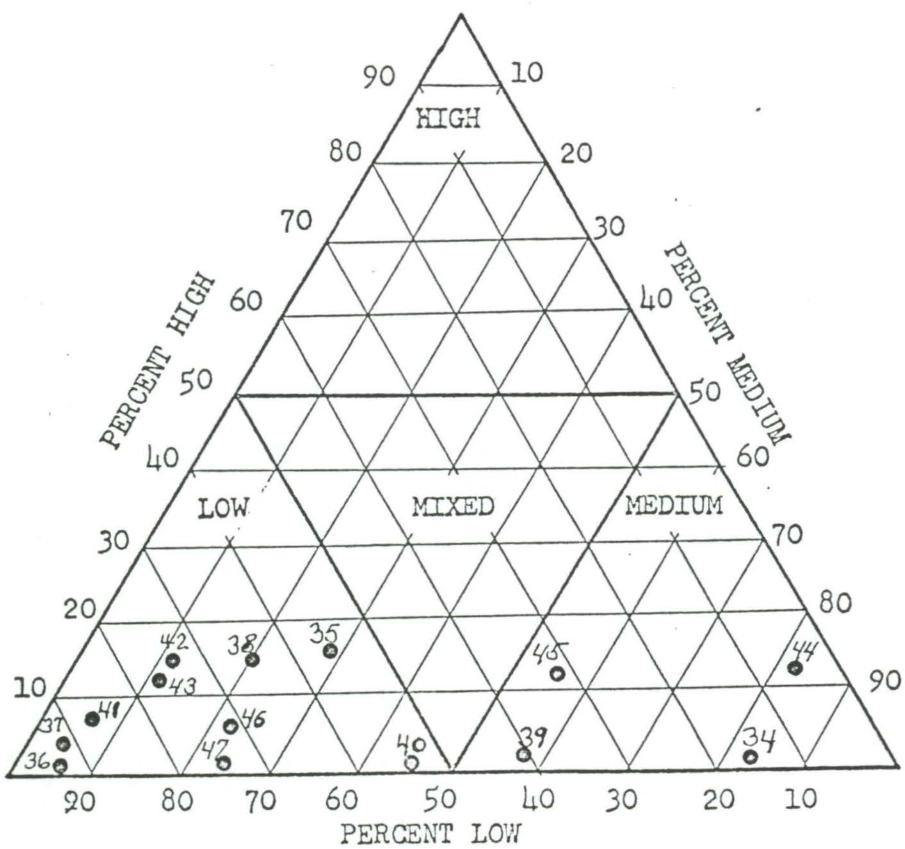


Fig. 4. Percent Composition of Preference Groups in Red and White Pine Communities

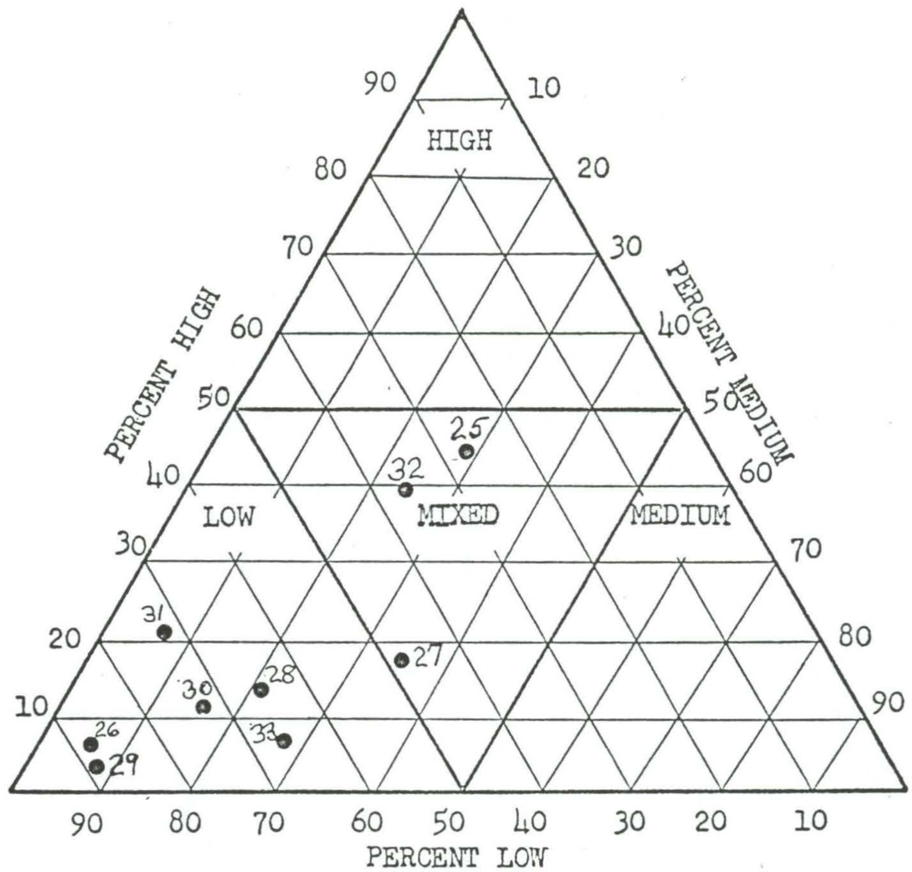


Fig. 5. Percent Composition of Preference Groups in Jack Pine Communities

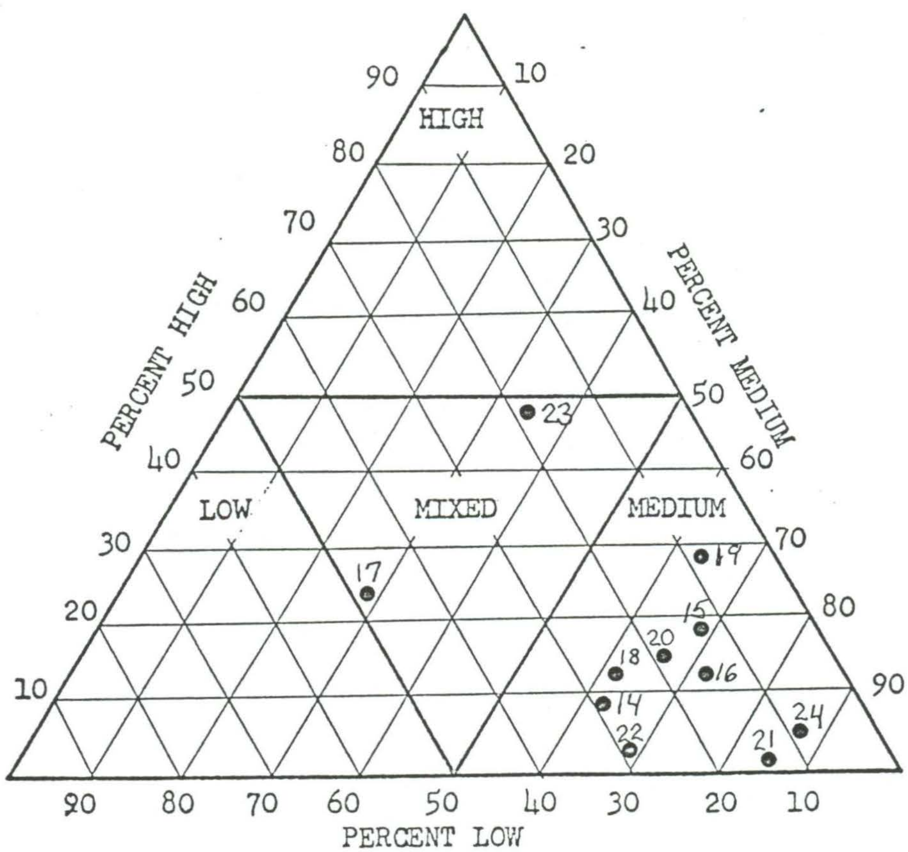


Fig. 6. Percent Composition of Preference Groups in Northern Hardwood Communities.

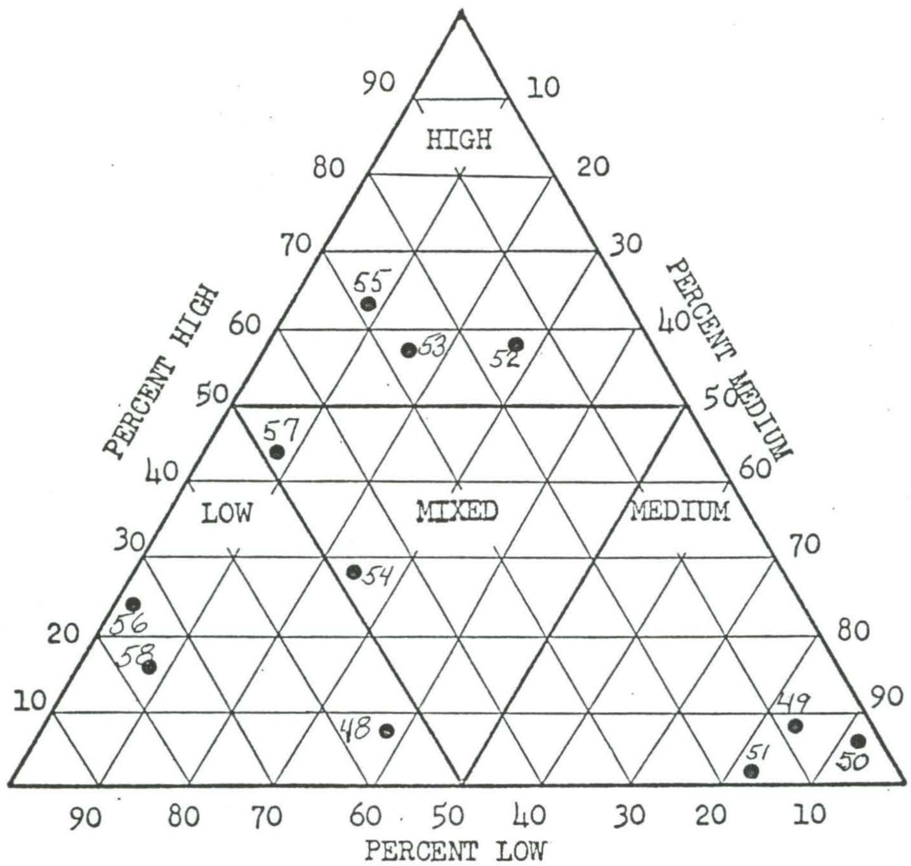


Fig. 7. Percent Composition of Preference Groups in Spruce-Fir, Lowland Hardwoods, Black Spruce, and Cedar Communities.

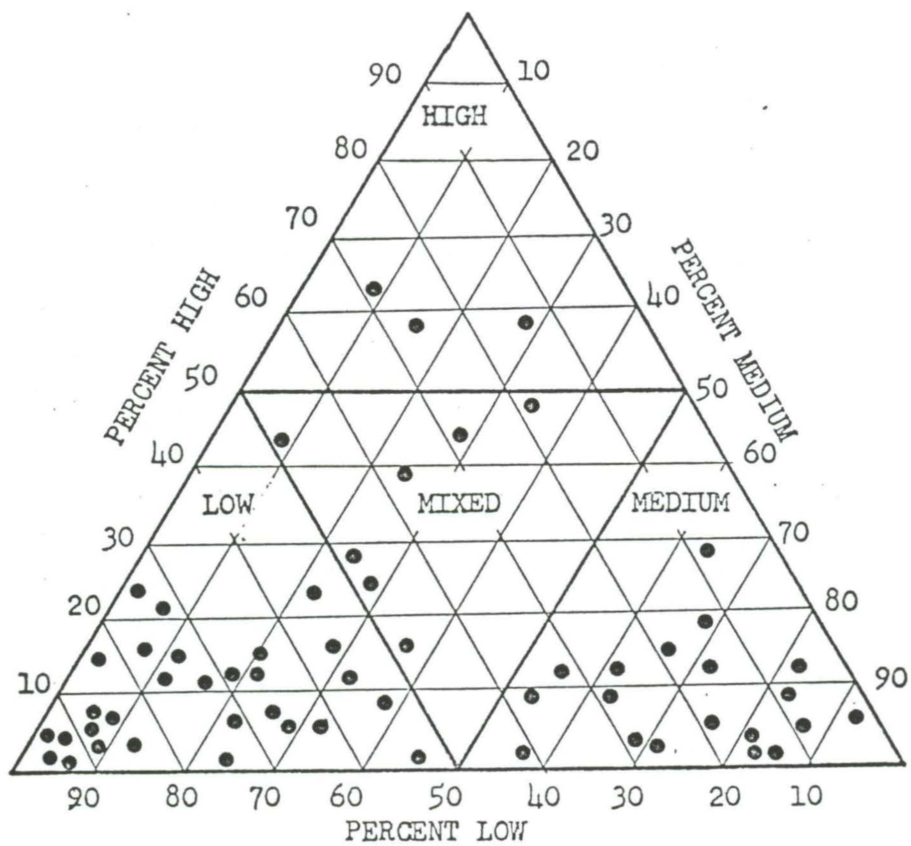


Fig. 8. Percent Composition of Preference Groups for All Communities Sampled.

The pattern of distribution of the coordinate values for the aspen-birch communities (Fig. 3) appears to be quite similar to the area occupied by the value for the red and white pine communities in Figure 4. Both cover types had a characteristically higher compostion of low preference species than either medium or high preference species. The percent composition of medium preference species exceeded the low preference composition in only three of the aspen-birch communities. The highest composition value of high preference species in this cover type was 26 percent.

Four communities within the red and white pine cover type were composed of a higher percentage of medium than low browse preference species. The highest composition value for high preference species was only 15 percent.

Seven of the jack pine communities were predominately composed of low preference species, and two communities were highest in the composition of high preference species as illustrated in Figure 5. These two communities were composed of an almost equal percent of low, medium, and high preference species as indicated by their graphical locations. Except for the graphical locations of these two communities, the distributional pattern is quite similar to the aspen-birch and red and white pine cover type graphs.

The pattern of coordinate locations in Figure 6 for the northern hardwood cover type is quite easily discernible from the three preceeding graphs. Northern hardwood communities were composed mainly of medium preference species. Only one community had its highest compositonal value (49%) for the low preference group, and another community consisted primarily of the high preference species (49%).

Figure 7 represents coordinate values for the spruce-fir (48-51), cedar (52), lowland hardwood (53-55), and black spruce (56-58) communities. The four spruce-fir communities had a very low composition of high preference species, although three of the communities had a minimum composition of 82% of the medium preference group. The lowland communities of black spruce, cedar, and lowland hardwoods were consistently low in the composition of the medium preference species. Two of the three lowland hardwood communities were dominated by high preference species. Each of the three black spruce communities was composed of primarily the low preference species. The cedar community had a high content, 59%, of the high preference group and 27% of the stems were of medium preference.

If a community consisted of more than 50% of either low, Medium, or High preference species; it was classified on the basis of the predominate preference group. Communities represented by less than 50% of the stems belonging to a specific preference group were classified as Mixed. Only 5% of the 58 communities sampled were classified as High. Mixed, Medium, and Low categories represented 12, 33, and 50%, respectively, of the communities.

Margalef (1958) has emphasized the importance of using "Information Theory" as a quantitative method for measuring the diversity of species for a community. Information theory involves determining the proportion of individuals of each species to the total number of individuals. For all practical purposes, information is considered to be equal to diversity. Mac Arthur and Mac Arthur (1961) have used this method for measuring bird species diversity. The formula for determining the species-diversity index is: $-\sum p_i \log_e p_i$, where p_i is the proportion of stems belonging to the ith species. A one species community has always zero diversity. If there are two species and there are 99 individuals of one species and one individual of another species then the diversity measure is: $-0.99 \log_e 0.99 - 0.01 \log_e 0.01 = 0.046 + 0.010 = 0.056$. If there are 50 individuals of one species and 50 of another species, diversity will be: $0.347 + 0.347 = 0.694$. The index value is greatest when the number of individuals is equal for each species represented.

Browse-species-diversity was determined for each community using the total number of browse stems less than seven feet in height. The browse-species-diversity indicies were compared to the frequencies of browsing for each community. The relationships are illustrated by cover types in Figures 9 through 12. The curves were fitted by the method of least squares.

Since index values do not indicate differences in browse preferences between species, it is possible that communities could have equal diversity values but widely varied browsing frequencies. For example, two communities with identical proportions for equal number of species would have the same browse-species-diversity index even though one community consisted of entirely low preference species and the other high preference species.

In spite of the limitations involved in using the formula for browse information, a linear relationship was found between the species diversity index and the percent of stems browsed for the communities in the aspen-birch, jack pine, and red and white pine cover types.

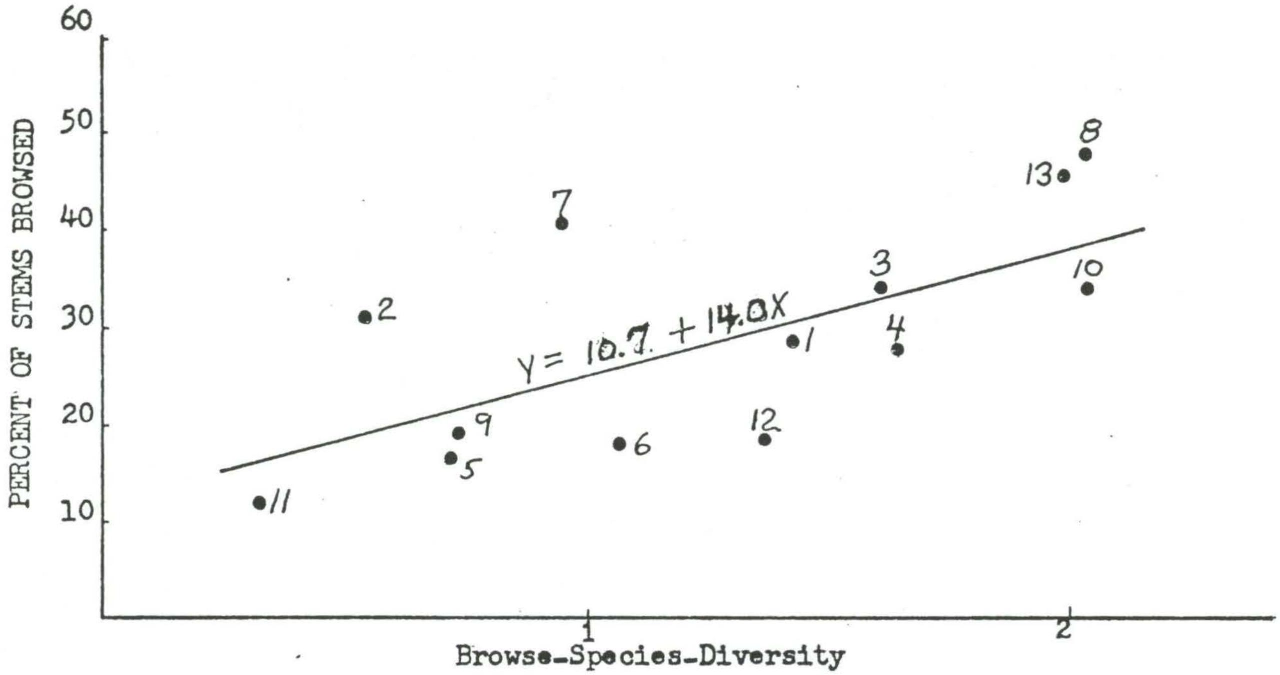


Fig. 9. Frequency of Browsing as Related to Diversity of Browse Species in Aspen-Birch Communities.

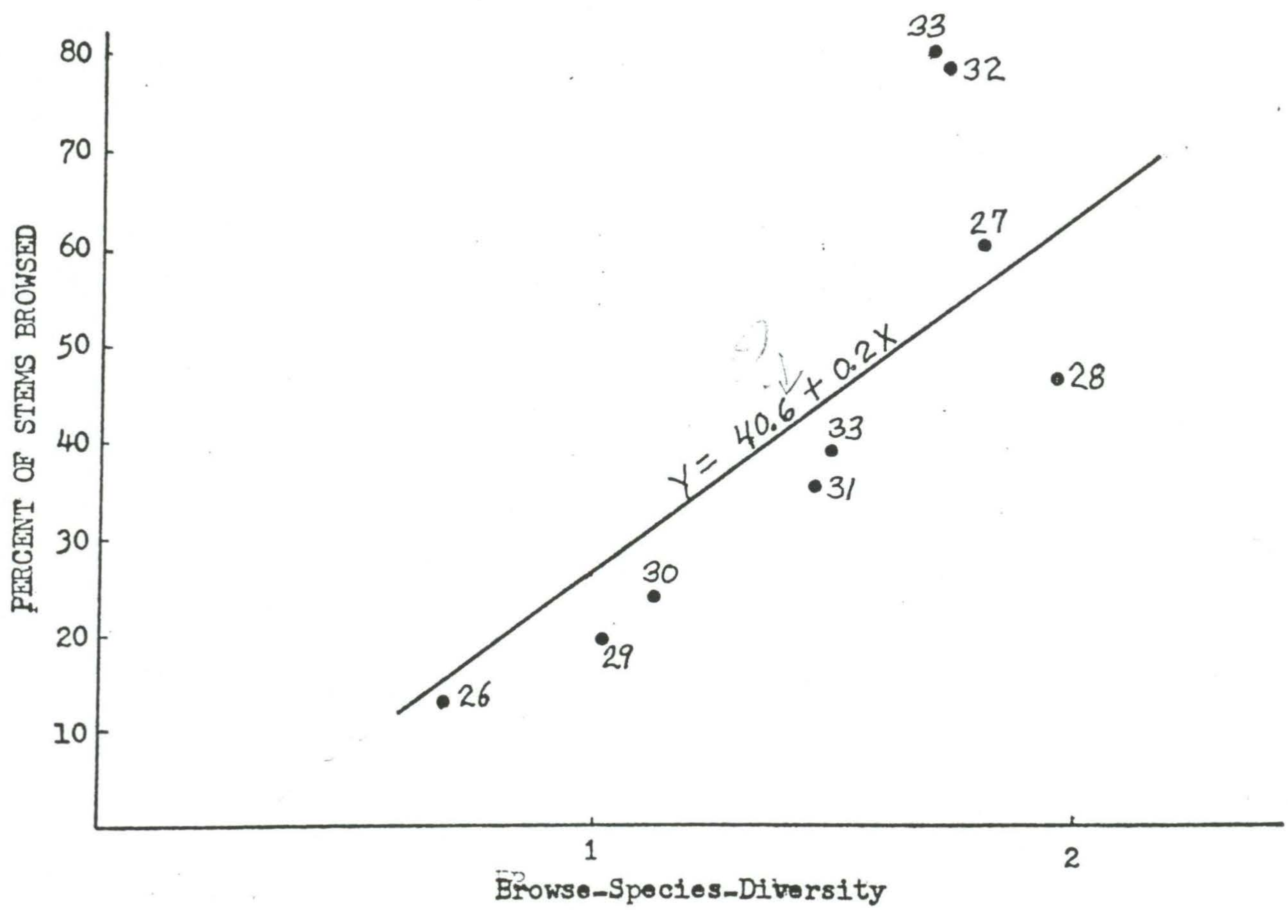


Fig. 10. Frequency of Browsing as Related to Browse Species Diversity in Jack Pine Communities.

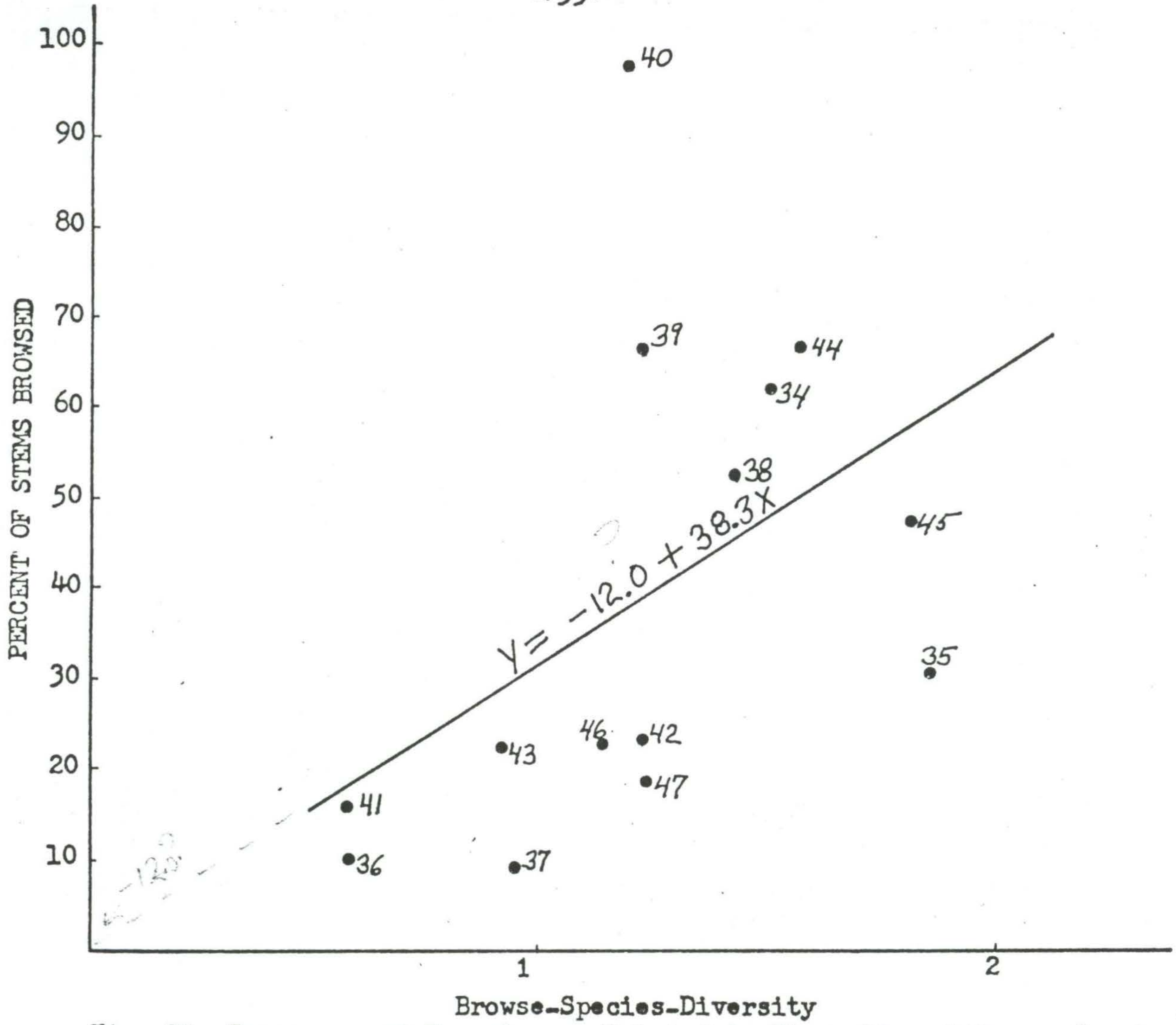
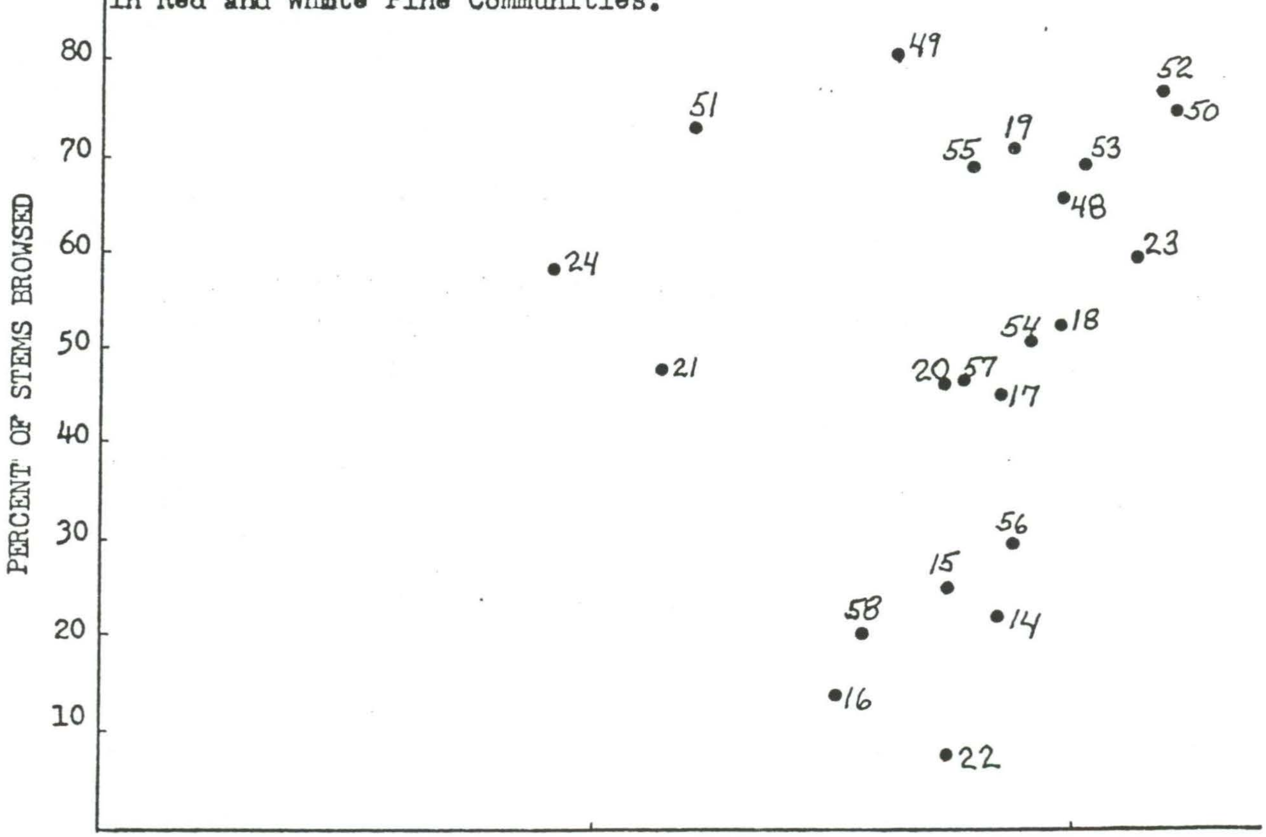


Fig. 11. Frequency of Browsing as Related to Diversity of Browse Species in Red and White Pine Communities.



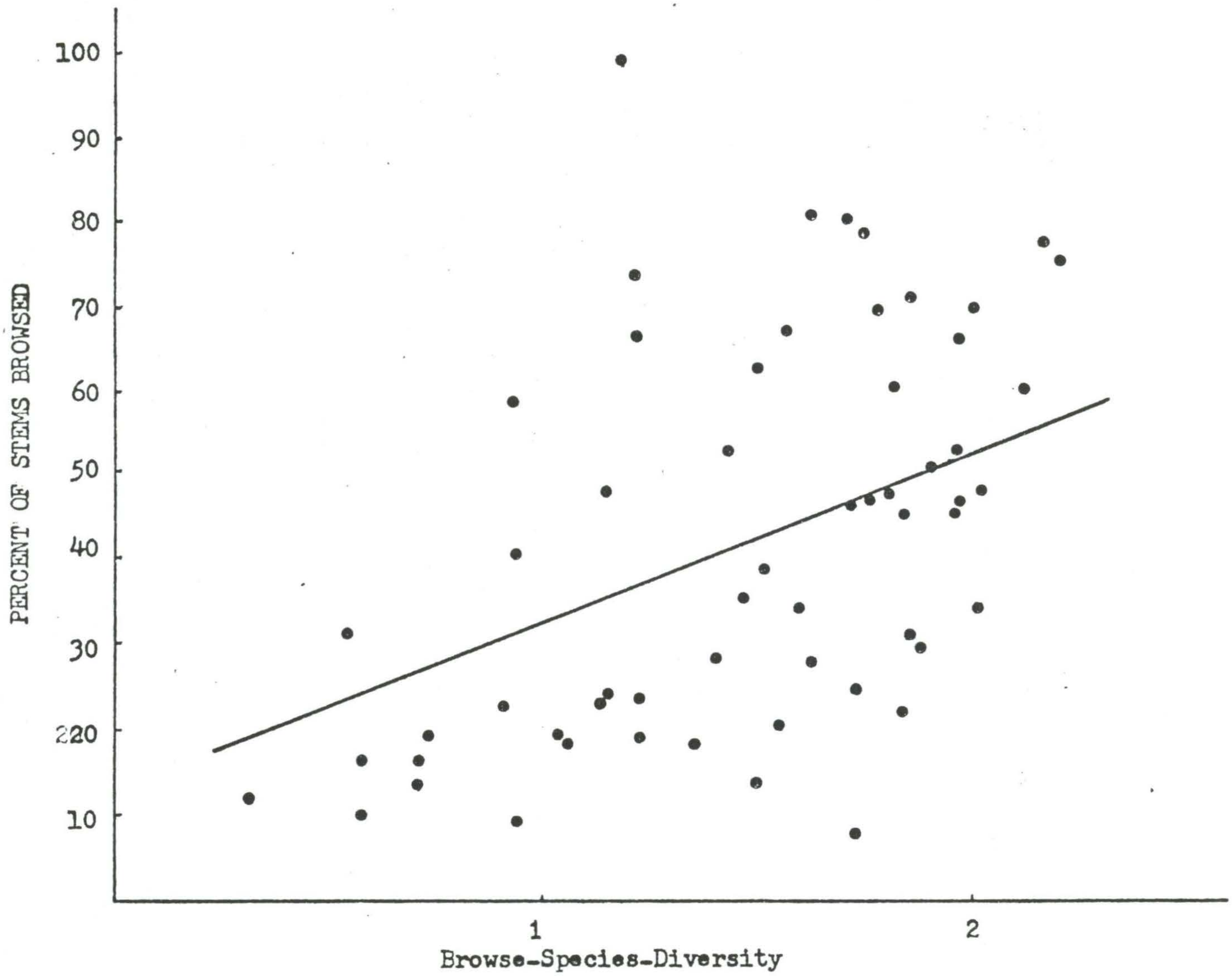


Fig. 13. Frequency of Browsing as Related to the Diversity of Browse Species in the Sampled Communities.

The curves for the jack pine and red and white pine types appear to be equal in slope while the slope of the relationship in the aspen-birch type is considerably less. A linear relationship did not appear to exist for the northern hardwood and lowland communities (Fig. 12). These communities had high diversity values but there was little variation in the values to reveal any linear relationship. The frequency of browsing was highly varied for these communities.

The linear relationship between the browsing frequency and browse-species-diversity for all 58 communities is shown in Figure 13. The regression equation is $Y = 12.9 + 19.6X$, and the correlation coefficient is $r = 0.63$. A significant trend existed for the frequency of browsing to increase with a relatively high correlation considering the range of variation in diversity for the northern hardwood and lowland communities.

Inspection of the graphical locations in Figures 9-13 for communities with low diversity indicies, indicated that many of these were categorized as consisting of low preference browse species (Figures 3-8). The average diversity indicies were determined for each of the Low, Medium, Mixed, and High categories. The respective average values were: Low - 1.19, Medium - 1.66, Mixed - 1.84, and High - 1.98. The trend for diversity to increase with the relative increase in browse preference groups was probably influenced by the density of hazel. Communities rated as Low were generally dominated by hazel, a low preference species, which resulted in a poor distribution of individuals per species, thus a low browse-species-diversity index.

To determine if the number of stems browsed per acre was related to the quantity of available stems of a species, three species representative of each preference group were selected for comparison. The species selected were mountain maple, juneberry, and beaked hazel. These species were chosen because they were the most abundant species occurring in many of the forest communities for their respective preference groups.

The density data for each species was plotted graphically as illustrated in Figures 14 and 15. The total number of stems less than seven feet in height was plotted on the ordinate axis, and the number of stems browsed per acre was plotted on the abcissa. Frequency of browsing was not used as the dependent variable because it would not indicate changes due to availability.

Mountain maple, a highly preferred species, had a very high correlation coefficient, $r = .98$, between the number of stems browsed and the actual density of the species. The regression equation is $Y = 0.9X - 14.8$ with 15 degrees of freedom.

Juneberry, a medium preference species, had a correlation coefficient equal to .90 and the regression equation is $Y = 0.6X - 41.2$ with 41 degrees of freedom. The slope of the curve was somewhat less than that for mountain maple.

Beaked hazel was the most abundant browse species in the study area. Comparing the number of stems browsed to the actual density of the stems revealed a positive linear relationship; $Y_1 = 873.4 + 0.05X$, with a correlation coefficient of .31 with 49 degrees of freedom; as shown by Y_1 in Figure 15.

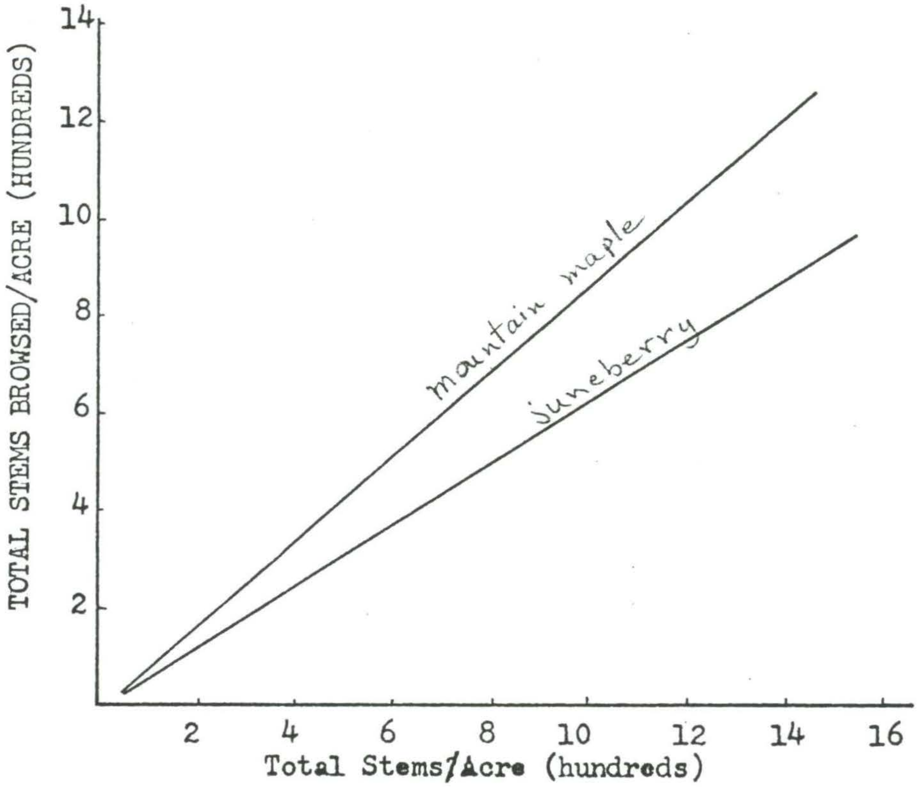


Fig. 15. Relationship of the Density of Browsed Stems to the Total Available Stems for Mountain Maple and Juneberry.

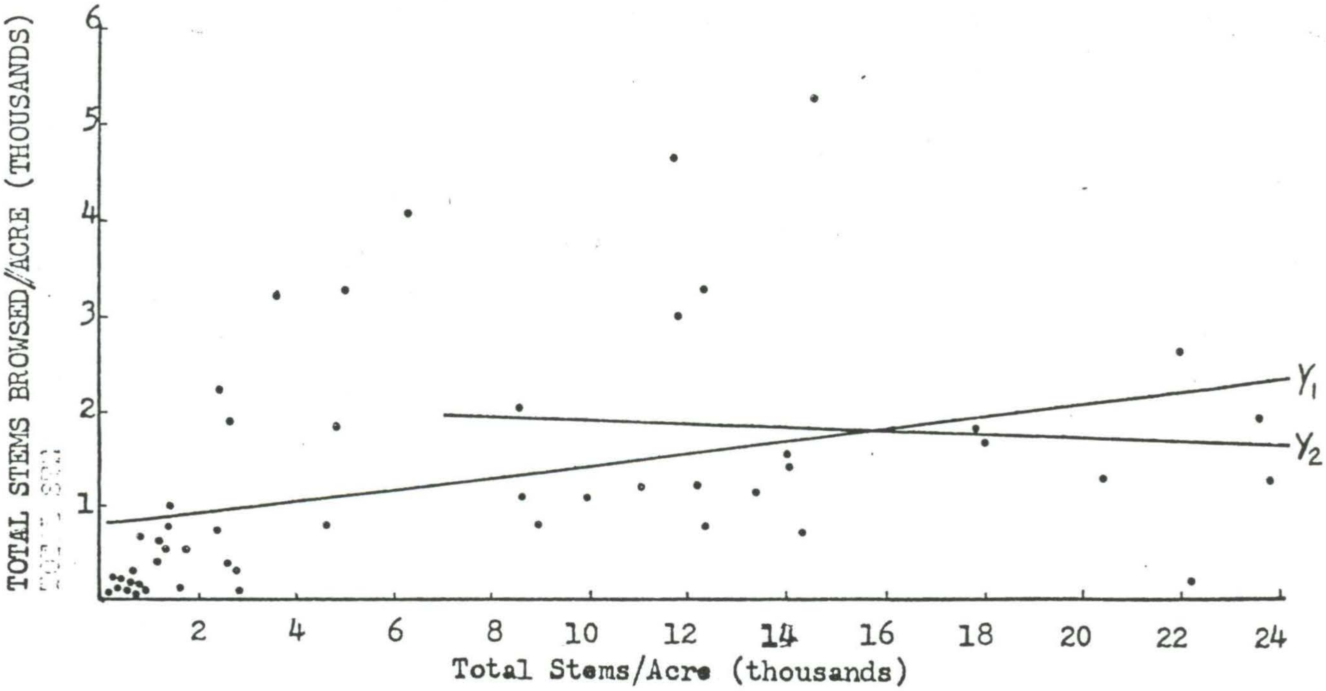


Fig. 16. Relationship of the Density of Browsed Hazel to the Total Available Stems (Y_1). Y_2 is the Relationship for Communities with More Than 7500 Hazel Stems/Acre.

Inspection of the pattern of plotted coordinates for communities with more than 7500 stems per acre indicated little or no increase in the actual number of hazel stems browsed per acre. The regression equation was computed for data over 7500 stems per acre, and the resulting relationship is shown by Y_2 in Figure 15. The regression equation was $Y = 2138 - 0.02X$. The slope of the curve was statistically analyzed to determine if it was significantly different from zero. Student's t test was used, and the observed t value was 0.074 which was not significantly greater than the tabular value for $\alpha = .05$ with 21 degrees of freedom. Interpretation of the analysis revealed that the number of hazel stems browsed remained constant or did not increase for forest communities with more than 7500 stems of hazel per acre.

Total stem age was considered as a factor that might influence the selection of stems for browse food. Previous studies have shown that protein content of stems decrease as the plants mature (Leopold, et. al., 1951; Dietz, et. al., 1958). Palatability of browse was considered to be influenced by plant maturity. For comparing the effects of stem age on browse preference, data on hazel stems was used.

Of the the total browsed stems, the percent within each two-year age class was determined and compared to the percent of the total available browse stems within each age class. The results are presented in Figure 16. An apparent preference for relatively younger stems existed. An estimated 40% of the browsed stems were 4-5 years old while only 27 percent of the total stems represented this age class. The percent of stems browsed was higher than the percent of total stems for each age class for stems less than seven years old, after which the reverse was true.

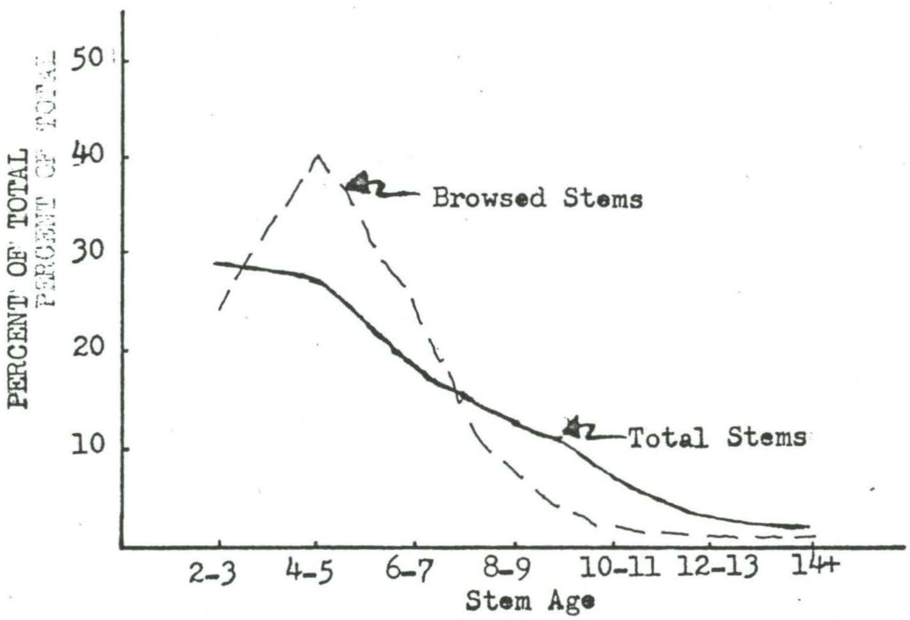


Fig. 16. Browse Preference of Hazel as Influenced by Stem Age.

Browsing on conifer seedlings

White and jack pine were rated as high preference species with 85 and 100%, respectively, of the seedlings being browsed by deer and hare. Balsam fir seedlings were 53% browsed - 25% by hare. White and black spruce, and red pine were very seldom browsed by deer but more often by hare.

Tables 6 through 13 give the distribution and average density of the conifer seedlings greater than 12 inches in height. White pine seedlings were most abundant in jack pine communities, and many of these occurred in a stand that had been logged by forestry students. Average density in all jack pine communities sampled was 520 white pine seedlings per acre, and in the red and white pine types density was 215 seedlings per acre.

Red pine seedlings did not average more than 50 seedlings per acre for any of the cover types and were not listed in the tables. Jack pine seedling density was estimated at only 80 per acre in the jack pine type, where the majority were present.

Balsam fir seedlings were found more extensively throughout the park. The respective average densities for the red and white pine, lowland hardwood, black spruce, aspen-birch, and spruce-fir cover types were: 773, 220, 178, 126, and 61 seedlings per acre. At least 90% of the fir seedlings in the aspen-birch type were present in one community that was recently logged before the area was acquired for the park.

Black spruce seedlings averaged 271 individuals per acre in the black spruce cover type. White spruce and cedar seedlings averaged less than 50 stems per acre in all cover types.

As explained previously, the intensity of browsing on conifer seedlings was estimated based on the number and amount of shoots that had been browsed. The seedlings were assigned a browse form class value from 0 (not browsed) to 4 (severely browsed). The seedlings were grouped by species into height classes and the percent of seedlings, based on the number within a given height class, within each form class was determined. The results are given in Table 15. through 21.

Sixty-nine percent of the white pine seedlings observed were browsed, and 83% of the seedlings greater than 12 inches in height were browsed. The intensity of browsing was light for most of the seedlings as 45% of those 12 inches or more were form class 1. About 30% of the seedlings between 6 and 24 inches were either heavily or severely browsed. Most of the white pine seedlings over three feet were only lightly or moderately browsed.

Only 32 red pine seedlings were observed in the entire survey. Two-thirds of the seedlings were not browsed and only one was heavily browsed with the remainder lightly or moderately browsed. The seedlings were all less than five feet in height.

Jack pine seedlings were also scarce as only 31 were observed. All of the seedlings were browsed and 20 were severely browsed. Five seedlings that were over seven feet in height were the only lightly browsed individuals.

Browsed balsam fir seedlings were generally in form class 1 and 47% of the total seedlings over 12 inches were not browsed. Only 26% of the seedlings less than 6 inches were browsed. Form class 3 and 4 accounted for 13% of the stems over 12 inches and these were usually less than 3 feet in height.

Table 15. Intensity of Browsing on White Pine Seedlings for Different Height Classes

Height Class (in.)	0 No.	0 %	1 No.	1 %	2 No.	2 %	3 No.	3 %	4 No.	4 %	Total no. of seedlings
1-5	42	69	2	3	7	11	6	10	4	7	61
6-12	32	34	14	15	17	18	10	11	21	22	94
13-24	20	25	17	21	21	26	9	11	13	16	80
25-36	4	17	9	39	4	17	5	22	1	4	23
37-48	6	32	7	37	4	21	1	5	1	5	19
49-60	1	6	9	56	5	31	-	-	1	6	16
61-72	-	-	10	67	4	27	1	7	-	-	15
73-84	-	-	9	75	3	25	-	-	-	-	12
85+	1	4	24	96	-	-	-	-	-	-	25
Ave. for all seedl.		31		29		19		9		12	
Ave. for seedl. > 12"		17		45		22		8		8	

Table 16. Intensity of Browsing on Red Pine Seedlings for Different Height Classes

Height Class (in.)	0 No.	0 %	1 No.	1 %	2 No.	2 %	3 No.	3 %	4 No.	4 %	Total no. of seedlings
1-5	-	-	-	-	-	-	-	-	-	-	-
6-12	4	80	1	20	-	-	-	-	-	-	5
13-24	5	63	2	25	1	12	-	-	-	-	8
25-36	6	75	2	25	-	-	-	-	-	-	8
37-48	4	57	1	14	1	14	1	14	-	-	7
49-60	2	50	1	25	1	25	-	-	-	-	4
61-72	-	-	-	-	-	-	-	-	-	-	-
73-84	-	-	-	-	-	-	-	-	-	-	
85 +	-	-	-	-	-	-	-	-	-	-	-
Ave. for all seedl.		66		22		9		3		-	
Ave. for seedl. > 12"		63		22		11		4		-	

Table 17. Intensity of Browsing on Jack Pine Seedlings for Different Height Classes

Height Class (in.)	0 No.	0 %	1 No.	1 %	2 No.	2 %	3 No.	3 %	4 No.	4 %	Total no. of seedlings
1-5	-	-	-	-	-	-	1	17	5	83	6
6-12	-	-	-	-	1	11	1	11	7	78	9
13-24	-	-	-	-	1	12	1	12	6	75	8
25-36	-	-	-	-	-	-	-	-	-	-	-
37-48	-	-	-	-	-	-	-	-	1	100	1
49-60	-	-	-	-	-	-	-	-	-	-	-
61-72	-	-	-	-	-	-	-	-	-	-	-
73-84	-	-	-	-	-	-	-	-	1	100	1
85 +	-	-	5	83	1	17	-	-	-	-	6
Ave. for all seedl.		-		16		10		10		64	
Ave. for seedl. > 12"		-		32		12		6		50	

Table 18. Intensity of Browsing on Balsam Fir Seedlings for Different Height Classes.

Height Class (in.)	Browse Form Class 0 No.	0 %	1 No.	1 %	2 No.	2 %	3 No.	3 %	4 No.	4 %	Total no. of seedling
1-5	235	74	20	6	21	7	24	8	18	6	318
6-12	140	42	51	15	57	17	35	11	48	14	331
13-24	42	43	19	20	13	13	9	9	14	14	97
25-36	27	42	22	34	6	9	6	9	4	6	65
37-48	13	39	17	52	2	6	-	-	1	3	33
49-60	19	70	6	22	2	7	-	-	-	-	27
61-72	10	46	12	54	-	-	-	-	-	-	22
73-84	7	78	2	22	-	-	-	-	-	-	9
85 +	6	75	2	25	-	-	-	-	-	-	8
Ave. for all seedl.		55		17		11		8		9	
Ave. for seedl. > 12"		47		31		9		6		7	

Table 19. Intensity of Browsing on White Spruce Seedlings for Different Height Classe

Height Class (in.)	Browse Form Class 0 No.	0 %	1 No.	1 %	2 No.	2 %	3 No.	3 %	4 No.	4 %	Total no. of seedling
1-5	16	94	-	-	-	-	-	-	1	6	17
6-12	15	47	12	38	1	3	1	3	3	9	32
13-24	5	45	3	27	1	9	2	18	-	-	11
25-36	3	50	2	33	-	-	1	17	-	-	6
37-48	2	67	1	33	-	-	-	-	-	-	3
49-60	2	67	1	33	-	-	-	-	-	-	3
61-72	1	100	-	-	-	-	-	-	-	-	1
73-84	2	100	-	-	-	-	-	-	-	-	2
85 +	-	-	-	-	-	-	-	-	-	-	-
Ave. for all seedl.		62		25		3		5		5	
Ave. for seedl. > 12"		57		27		4		12		-	

Table 20. Intensity of Browsing on Black Spruce Seedlings for Different Height Classe

Height Class (in.)	Browse Form Class 0 No.	0 %	1 No.	1 %	2 No.	2 %	3 No.	3 %	4 No.	4 %	Total no. of seedling
1-5	28	100	-	-	-	-	-	-	-	-	28
6-12	38	97	1	3	-	-	-	-	-	-	39
13-24	23	85	4	15	-	-	-	-	-	-	27
25-36	4	100	-	-	-	-	-	-	-	-	4
37-48	-	-	-	-	-	-	-	-	-	-	-
49-60	1	100	-	-	-	-	-	-	-	-	1
61-72	-	-	-	-	-	-	-	-	-	-	-
73-84	-	-	-	-	-	-	-	-	-	-	-
85 +	-	-	-	-	-	-	-	-	-	-	-
Ave. for all seedl.		95		5		-		-		-	
Ave. for seedl. > 12"		88		12		-		-		-	

Table 21. Intensity of Browsing on N. White Cedar for Different Height Classes.

Height Class (in.)	Browse Form Class 0 No.	0 %	1 No.	1 %	2 No.	2 %	3 No.	3 %	4 No.	4 %	Total no. of seedlings
1-5	23	92	-	-	2	8	-	-	-	-	25
6-12	17	71	1	4	3	12	3	12	-	-	24
13-24	3	100	-	-	-	-	-	-	-	-	3
Ave. for all seedl.		82		2		10		6		-	

Fifty-seven percent of the white spruce seedlings over 12 inches were not browsed and 27% were only lightly browsed. None of the seedlings were severely browsed. Only one seedling less than six inches was browsed.

Black spruce was of very low preference and only 12% of the seedlings over 12 inches were browsed. The form class rating for the browsed seeedlings was light. None of the seedlings less than six inches was browsed.

Only 8 of the 42 cedar seedlings observed were browsed and only three of total were over 12 inches in height. All of the cedar seedlings were found under fallen trees or between hummocks and were probably covered by snow and/or were unavailable for deer or hare to browse.

The intensity of browsing of conifers was also determined by comparing the percent of branches browsed according to seedling age classes. The response to levels of browsing was considered to be indicated by the length of the current years leader. The results are presented according to species in Tables 22 through 26. Zero values for leader length indicate that the leaders were browsed or damaged and showed no 1965 terminal growth.

White pine seedlings that were 7 years or older had 25 to 30% of the branches browsed and deer were the primary browsers. Leader length showed a direct increase as the age of the seedlings increased.

Red pine branches were browsed only by hare. Three 15-year old seedlings had an average of 33% of the branches browsed, but most of the branches for all of the seedlings were unbrowsed.

The frequency of browsing on balsam fir branches was about 10-15% less than on white pine, and a higher proportion of the browsed

Table 22, Percent of Branches Browsed by Deer and Hare and 1965 Leader Length of White Pine Seedlings According to Year Class.

Age	Branches				Leader	No. of
		% Browsed				
	Ave. No.	Deer	Hare	Total	Lgth. (in.)	Seedlings
3	0	0	0	0	1	7
4	<1	60	0	60	1	16
5	1	0	0	0	1	15
6	1	3	0	3	1	21
7	3	47	4	51	1	23
8	3	6	9	15	2	19
9	3	20	8	28	2	17
10	6	18	5	23	2	28
11	8	12	10	22	2	17
12	9	20	13	33	2	30
13	11	16	8	24	3	42
14	13	19	11	30	4	30
15	18	23	6	29	7	30
16	21	22	2	24	7	13
17	23	25	6	31	7	16
18	26	17	5	22	9	6
19	26	21	7	28	10	7
20	28	14	0	14	14	1
21	28	29	0	28	6	1

Table 23. Percent of Branches Browsed by Deer and Hare and 1965 Leader Length of Red Pine Seedlings According to Year Class.

Age	Branches				Leader	No. of
		% Browsed				
	Ave. No.	Deer	Hare	Total	Lgth. (in.)	Seedlings
4	2	0	0	0	1	1
5	0	0	0	0	2	2
7	1	0	0	0	2	2
8	5	0	0	0	3	1
9	6	0	25	25	2	2
10	3	0	0	0	2	2
11	5	0	11	11	3	5
12	9	0	0	0	4	3
13	7	0	0	0	0	1
14	10	0	0	0	4	5
15	14	0	33	33	4	3
16	7	0	8	8	2	2
17	10	0	0	0	8	1
18	9	0	55	55	2	1
19	16	0	19	19	8	1

Table 24. Percent of Branches Browsed by Deer and Hare and 1965 Leader Length of Jack Pine Seedlings According to Year Class.

Age	Branches				Leader	No. of
		% Browsed				
	Ave. No.	Deer	Hare	Total	Lgth. (in.)	Seedlings
7	2	44	33	77	2	6
8	3	47	44	91	2	11
10	3	0	50	50	0	2
12	4	29	29	58	2	2
14	8	75	0	75	2	1
15	4	0	100	100	0	1
16	8	25	38	63	3	1
20	16	43	0	43	8	3

Table 25. Percent of Branches Browsed by Deer and Hare and 1965 Leader Length of Balsam Fir Seedlings According to Year Class.

Age	Branches				Leader	No. of
		% Browsed				
	Ave. No.	Deer	Hare	Total	Lgth. (in.)	Seedlings
3	1	0	0	0	1	13
4	2	13	6	19	1	19
5	2	21	14	35	1	28
6	3	19	3	22	1	29
7	5	9	6	15	1	34
8	8	10	2	12	2	44
9	14	2	1	3	3	45
10	13	11	6	17	3	32
11	18	7	5	12	3	25
12	17	5	5	10	3	46
13	24	1	4	5	5	33
14	20	3	10	13	3	42
15	24	4	6	10	4	42
16	26	6	10	16	4	19
17	41	1	4	5	7	11
18	34	3	3	6	7	7
19	48	0	3	3	6	2

Table 26. Percent of Branches Browsed by Deer and Hare and 1965 Leader Length of White Spruce Seedlings According to Year Class.

Age	Branches				Leader	No. of
		% Browsed				
	Ave. No.	Deer	Hare	Total	Lgth. (in.)	Seedlings
5	2	0	0	0	1	1
6	5	6	0	6	3	3
8	11	0	6	6	2	3
9	11	0	6	6	2	3
11	20	0	3	3	2	3
12	21	0	0	0	1	1
13	26	0	0	0	4	3
14	41	0	0	0	4	2
15	37	0	0	0	5	1
18	80	0	0	0	11	1
22	7	0	0	0	0	1

branches were nipped by hares. The percent of the browsed also showed a reduction as age increased. The leader length also increased with age.

White spruce branches were seldom browsed and, if ever, only by hares. The highest frequecny of browsed branches was only 6% and occurred for 8 and 9-year old seedlings.

A comparison of the percent of terminal leaders browsed to seedling heights was made for browsed conifer seedlings, and the results are shown in Table 27. Browsed jack pine seedlings less than 6 feet in height had 100% of the leaders browsed, and red pines had the lowest proportion (27%). Browsed white pine, balsam fir, white spruce, and black spruce had 64, 58, 45, and 40%; respectively, of the leaders browsed. Hares were the primary leader browsers of red pine, white and black spruce, and balsam fir.

As would be expected, a decrease in the frequency of browsed leaders occurred as seedling height increased. After seedlings reached $4\frac{1}{2}$ to 5 feet in height, they were seldom terminally browsed.

An original objective of this study was to determine the extent of conifer seedling mortality that resulted from overbrowsing. Because of the difficulties in determining the causes of mortality and the disappearance of seedlings after they were killed by browsing or other causes, it was considered too difficult to document mortality reliably. It was concluded that seedling mortality was not due to overbrowsing or that dead stems did not remain erect during the summer months. It was also possible thatdead stems may not have been observed on plots where the cover of lesser vegetation was abundant.

Table 27. Percent of Browsed Conifers with Terminal Leaders Browsed by Deer and Hare for Different Seedling Height Classes.

Height (in.)	White Pine			Red Pine			Jack Pine			Balsam Fir			White Spruce			Black Spruce		
	Deer	Hare	Total	Deer	Hare	Total	Deer	Hare	Total	Deer	Hare	Total	Deer	Hare	Total	Deer	Hare	Total
1-5	74	16	90	-	-	-	67	33	100	23	66	89	100	0	100	0	0	0
6-12	45	42	87	0	0	0	40	60	100	33	36	69	6	64	70	0	100	100
13-24	37	28	65	0	33	33	43	57	100	12	28	40	0	16	16	0	25	25
25-36	26	26	52	0	50	50	-	-	-	0	10	10	0	33	33	0	0	0
37-48	15	8	23	0	33	33	100	0	100	15	0	15	0	0	0	-	-	-
49-60	27	7	34	0	0	0	~~6~~	-	-	6	0	6	0	0	0	0	0	0
61-72	13	0	13	0	0	0	-	-	-	0	0	0	0	0	0	-	-	-
73-84	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	-
85 +	4	0	4	0	0	0	0	0	0	0	0	0	-	-	-	-	-	-
Ave. for Seedlings $\leq$ 72"			64			27			100			58			45			40

When dead seedlings were observed and mortality was believed attributable to overbrowsing, the stems were counted. The ratio of dead stems to living seedlings for the actual observations recorded was: jack pine - 1/4, white pine - 1/49, and balsam fir - 1/65. Dead seedlings of other coniferous species were not observed.

Blister rust information was also recorded when the disease was observed on white pine seedlings. Twenty-seven seedling or 10% of the seedlings greater than 6 inches in height had symptoms of the disease. The average age and height of the infected seedlings were 13 years and 27 inches. These seedlings were generally moderately browsed and the average 1965 leader length was 2 inches.

DISCUSSION

Itasca Park has a relatively wide variety of browse species which is probably influenced by the geographical location of the area since it lies between the conifer region to the north, the hardwood region to the south, and prairie region to the west. The availability of several woody plant species was probably the reason that there was not any great difference in the frequency of browsing between the adjacent species in the ranked preference list given in Table 5.

Comparing the Itasca preference list with the preference list Tamarac Refuge (Table 3) reveals some differences in species ratings. Downy arrowwood, panicled dogwood, and bur oak were rated higher for Tamarac than for Itasca. This may have resulted from differences in availability of other species or cover (shelter) conditions. If some of the high preference Itasca species, for example mountain maple, did not occur in Tamarac, deer would utilize these species as substitutes. In Itasca, these three species were most abundant in the aspen-birch communities where the intensity of browsing was not as great compared to the other forest communities.

Rose, prairie willow, and elm were rated higher for Itasca than for Tamarac. This was probably related to the cover type in which the species occurred most frequently. The first two species were most common in the jack pine type and the latter in the lowland hardwood type. The jack pine type was probably used more extensively because of the shelter afforded by the coniferous canopy even though the preference group compositions (Figs. 3 and 5) were similar to the aspen-birch type. The lowland hardwood communities were near coniferous communities, and it appeared that these general areas were used more extensively by wintering deer than were other upland areas. However, general browsing conditions did not indicate that these areas were heavily used deer concentration or yarding areas.

The importance of browse availability as a factor influencing the frequency of browsing is indicated by comparing the utilization of woody species in the spruce-fir type (Table 10) to the other cover types. In this type the density of browse was relatively very low and stems were intensively browsed indicating that deer were not as selective in this type but rather were utilizing anything that was available. The number of deer that the spruce-fir type could support would be quite low because of the very low density of the food supply. Cover apparently was an important factor influencing the use of the spruce-fir type. The coniferous canopy provided shelter from adverse weather conditions.

Coniferous shelter was lacking in the aspen-birch type and this was probably the reason that this type was not extensively used. Aspen-birch communities had a low density of high preference species (Table 14) but even though availability of these species was low the frequency of utilization was less than in most of the types.

Figure 13 shows that the frequency of browsing increased as the species-diversity increased. The importance of a variety of browse species as a factor affecting utilization was not as evident in the northern hardwood type. In this type the frequency of browsing was highly varied even though the diversity indicies were approximately equal. The decrease in the extent of browsing in this type compared to the other types may have resulted from the lack of a coniferous canopy or may have occurred because the deer had a better selection of forage material and thus did not browse as many plants to fulfill their dietary requirements. One reason for the greater diversity index values in the northern hardwood type was due to the decrease in hazel abundance which resulted in a better proportionate distribution of the individuals of the other indigenous species.

Hazel brush was an important browse species in the upland communities because it was the most abundant species inhabiting the area. In the northern hardwood type, hazel comprised only 12% of the total browse stems. In the jack pine, aspen-birch, and red and white pine types; hazel constituted 58, 67, and 70%; respectively, of the available browse. Since it was a low preference species, its occurrence was very significant if affecting the diversity values of the upland communities. In areas where hazel was relatively dense, the deer browsed more intensively on the more preferred species (Tables 6 and 7).

The average density of hazel within the jack pine, red and white pine, and aspen-birch cover types was approximately 8000, 11000, and 12000 stems per acre; respectively. As shown in Figure 16 the actual number of hazel stems browsed in communities with more than 7500 hazel stems per acre remained constant. Thus, the pine communities had at least 2000 hazel stems that were not contributing to the browse supply. If the density of hazel was reduced and their ecological niche was replaced by more preferred species, the carrying capacity of the communities could be increased because the utilization of these species would increase as the abundance of the species increased as shown in Figure 15.

French and McEwen (1955) and Dietz, et.al. (1958) have found that deer need a variety of woody plant species in their diet to fulfill nutritional requirements for optimal growth and body maintenance. This information suggests that areas under intensive deer management should be managed to provide a browse supply consisting of many species. The browse-species-diversity indicies could be used as indicators of the condition of forest communities in reference to both quantity and quality of the forage. Communities with higher diversity values would generally provide a more desirable browse supply than areas with low index values. It is also possible to determine the contribution of each species in comparison to the other species, using formula recommended by Margalef (1958) for localizing individual species contributions in respect to the total stand composition.

Browsing on Conifers

Because of the relatively low density of conifer seedlings; it was not possible to determine if the availability, including abundance and diversity, of deciduous browse plants influenced the frequency of browsing on conifers. Balsam fir was the most abundant conifer seedling, and field observations indicated that it was more frequently browded when the seedlings were less dense.

White and jack pine were highly preferred browse species. Balsam fir was a medium preference species, and the spruces and red pine were seldom browsed. The intensity of browsing on white pine averaged light to moderate, although seedlings less than two feet tall were frequently heavily or severely browsed (Table 15). Jack pine seedlings were severely browsed and only three or four branches remained on many of the seedlings.

Over 50% of the terminal leaders were nipped on browsed white and jack pine and balsam fir (Table 27). The effects of terminal browsing would reduce the rate of height growth if repeated for two or three years in succession (Marshall, et.al., 1955). The general appearance of the browsed white and jack pine seedlings indicated that they had been browsed at least two or three years previously. The height growth rate of pine seedlings was considered extremely low as many of the older seedlings should have been in the sapling or even tree size class. In addition to browsing, seedling growth was also believed to be hindered by the dense canopy of understory vegetation.

The significance of browsing on growth and establishment of pine seedlings would not be as great if a more adequate stocking of pine seedlings were present. Since these species are so limited in the park, any browsing results in serious results in terms of maintaining a representation of pine types. If the density of conifer seedlings were increased the relative effects of browsing on these species would decrease provided the deer population was maintained at a desirable level.

Suggestions for Future Studies

Collection of browse data information should be done in early spring when it is easier to identify current browsing injuries. After the woody plants have flushed out and the ground is covered with herbaceous plants, plot work is prolonged and complicated because browsed twigs are more difficult to see. However, it is possible to gather more information concerning the ecological characteristics of forest communities during the summer.

The importance of browse species diversity should be further investigated because of its relevance to areas under intensive management. A study of the effects of different silvicultural practices on the density and diversity of browse species would be of considerable value. This should include a synecological approach to determine the number and density of browse species that forest communities will produce, and the results should be correlated to actual deer use of the areas. Deer use should hot only be measured in terms of the frequency in which woody plants are browsed. Pellet group counts should also be made to compare the amount of use beteen different areas.

The relationship of the availability of deciduous browse to the frequency and intensity of browsing on conifer seedlings should be studied.

SUMMARY

A browse preference list,,based on 58 forest communities sampled, was compiled for Itasca State Park. Mountain maple, red maple, rose, red-osier and round leaved dogwoods, and prairie willow were the most abundant highly preferred browse species.

It was found that the frequency of browsing varied between cover types. Browsing frequency was generally greater in coniferous types than deciduous types. The frequency of browsing was dependent upon the canopy cover, density (number of stems per acre), and the availability of many browse species.

Based on the percent of the total stems within a community, the cover types were categorized as their composition of the three different preference groups as follows: aspen-birch - Low, red and white pine - Low, jack pine - Low, northern hardwoods - Medium, spruce-fir - Medium, cedar - High, lowland hardwoods - High, and black spruce - Low. Of the 58 communities sampled, only 5% were categorized as High. Mixed, Medium, and Low categories represented 12, 33, and 50%; respectively, of the communities.

It was found that increased diversity of available browse species led to an increase in the frequency of browsing. The browse species-diversity indicies increased as the dominant preference group compositions of communities changed from Low to High.

Hazel was the most abundant browse species, and the frequency of browsing on this species did not increase when the density of hazel was greater than 7500 stems per acre. For more preferred species, mountain maple and juneberry, the number of stems browsed increased as the density of the available browse stems of the species increased.

Conifer seedlings were found at very low densities with balsam fir being the most abundant seedling. White and jack pine were high preference species and balsam fir was of low preference. Red pine and the spruces were low preference species. In terms of the amount of annual growth browsed, jack pine was severely browsed and white pine was moderately browsed. Balsam fir, red pine, and the spruces were generally lightly browsed. Balsam fir was browsed more frequently by hares than by deer.

More than 50% of the conifer seedlings had the terminal shoots browsed. The 1965 leader length was very short, usually less than six inches.

The intensity of browsing did not appear to be causing severe mortality of conifers except on jack pine seedlings.

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Appendix

Table 28. Scientific and Common Names of Itasca Browse Species.

Scientific Name	Common Name
Abies balsamea	balsam fir
Acer rubrum	red maple
Acer saccharum	sugar maple
Alnus crispa	green alder
Alnus rugosa	speckled alder
Amelanchier spp.	juneberry
Betula alleghaniensis	yellow birch
Betula papyrifera	paper birch
Betula pumila	bog birch
Cornus alternifolia	alternate-leaved dogwood
Cornus racemosa	panicled dogwood
Cornus rugosa	round-leaved dogwood
Cornus stolonifera	red-osier dogwood
Corylus americana	American hazel
Corylus cornuta	beaked hazel
Diervilla lonicera	bush honeysuckle
Dirca palustris	leatherwood
Fraxinus nigra	black ash
Fraxinus pennsylvanica	green ash
Larix laricina	tamarac
Lonicera spp.	honeysuckle
Lonicera oblongifolia	swamp-fly-honeysuckle
Ostrya virginiana	ironwood
Picea glauca	white spruce
Picea mariana	black spruce
Pinus banksiana	jack pine
Pinus resinosa	red pine
Pinus strobus	white pine
Populus grandidentata	large-toothed aspen
Populus tremuloides	quaking aspen
Prunus pennsylvanica	pin cherry
Prunus serotina	black cherry
Prunus virginiana	choke cherry
Quercus macrocarpa	bur oak
Quercus rubra	red oak
Rhamnus alnifolia	alder-leaved buckthorn
Rosa spp.	rose
Salix humilis	prairie willow
Salix spp.	willow
Symphoricarpos albus	snowberry
Thuja occidentalis	Northern white cedar
Tilia americana	basswood
Ulmus americana	American elm
Viburnum rafinesquianum	downy arrowwood
Viburnum trilobum	highbush-cranberry